CRED

2011

Community Rural Electrification and Development

Damien Frame

University of Strathclyde

Acknowledgements

The CRED team owe a debt of gratitude to many colleagues at the University of Malawi Blantyre Polytechnic and University of Strathclyde Electronic and Electrical Engineering Dept.

In particular, special thanks are due to the Gambia Project, the Scotland Chikwawa Health Initiative and the Malawi Millenium Project for advice and support throughout the project duration. The input of Miss Sandra Picken in the field work and social analysis summarised in section 6.3 is gratefully acknowledged.

Further thanks and gratitude is extended to the Scottish Government International Development Team for their encouragement and support of the project.

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Executive Summary

The Community Rural Electrification and Development (CRED) project is one of three initiatives from the University of Strathclyde's Malawi Millennium Project that have received support from the Scottish Government's International Development Fund. The project arose from a growing interest within the University's Electrical Engineering Department on sustainable solar electricity deployments in the developing world and an ambition to address more of the wider sustainability challenges of solar electricity as well as the technical. The well established links between the University of Strathclyde (UoS) and the University of Malawi Blantyre Polytechnic provided the opportunity to undertake a project addressing the sustainability issues that undermine renewable energy solutions in Malawi.

A partnership consisting of staff from the University of Strathclyde, Blantyre Polytechnic and the Government of Malawi Department of Energy was subsequently formed and the Scottish Government funding granted at the end of October 2008 with the CRED project officially commencing November 2008.

The key principles of the CRED project are to improve the sustainability of rural PV deployments through deployment models focussing on community engagement and empowerment, local responsibility and income generation. Village energy committees backed up by an appropriate support chain of a local field coordinator, local suppliers and local government and academic partners are the foundation of the project.

Two high level project objectives were identified:

- To increase the opportunities for social and economic development through increased access to reliable, affordable electrical energy in rural communities.
- To develop and increase the capacity of key stakeholders to advance GoM off grid rural electrification programme.

The project efforts towards these objectives were centred around pilot installations in five communities in the Chikwawa district:

- Mwanayaya
- Namira
- Mikolongo
- Mwalija
- Chingoloma

And a further community Malavi which is peri-urban to Blantyre.

Project highlights include:

- 10 member Energy Committees formed, trained and well established in each of the communities
- 9 PV systems installed as a community resource, providing lighting, power, refrigeration and water pumping in schools and health posts

- A support chain of local field-worker and Blantyre based project management established
- A system of Energy Committee data recording established and 22 months of socio-economic data collected
- 834.3kWh of energy used by the communities for lighting that facilitates studying and community group activity
- 85.6kWh of energy used for charging phones
- 5448 hours of usefully lit rooms
- Over 17,000 recorded instances of a student using the facilities (this number does not describe 17,000 individuals, clearly many students have been using facilities on a regular basis)
- 52326 hours of student study time
- 6845 phones charged
- 215,000 Malawi Kwacha earned from income generation activities (approx £860)
- Local access to electrical energy for 6 villages (approximately 6000 people)
- Electronic data loggers collecting system performance and insolation data at two sites

As of March 2011 the CRED funding period expired and this report presents the results, learning and proposed approaches to improved sustainability for off-grid rural PV deployments.

1. Background

The Millennium Development Goals define the world's challenge when it comes to assisting developing countries. Underlying each MDG is an energy infrastructure requirement. The vital nature of sustaining existing energy supply or harnessing new energy supply to support development is emphasised by the recent UN General Assembly announcement that 2012 will be the '*International Year* of *Sustainable Energy for All',* and the International Energy Agency's Chief Economist calling for urgent action to secure adequate funding so that universal energy access can be achieved (UNIDO, 2011).

Increased electricity supply to the rural poor is widely acknowledged to be one of the main components of improved energy infrastructure in developing countries (World Bank/IEG, 2008). The benefits of electricity supply to the rural poor of developing countries may seem logical and it has long been claimed that electricity supply improves areas such as quality of life, education, health, economic productivity and more. However, there is a distinct lack of quantitative data to back up these claims. Rural electrification programmes that simply expand grid infrastructure only provide benefit to those able to afford connection and usage charges. The prohibitive cost and inability to achieve cost recovery presents a barrier to the Governments and energy companies in developing countries and hence RE has been a common focus of funding support.

The referenced IEG review considers World Bank financed rural electrification schemes in developing countries and reports on lessons learnt and conclusions. The majority of these schemes concentrate on grid infrastructure development. Significantly the report concludes that success has been measured by Outputs (infrastructure built) rather than Outcomes (impact on MDGs) and recommends that project design includes features such as financing schemes for connection charges, education of consumers and support for productive use. Typical cost-benefit analysis of rural electrification wraps all benefits within the household's 'willingness to pay'. However, in communities where 'ability to pay' is limited then the benefit of electricity supply in areas such as improved health, education, economic activity and environmental impact are much more difficult to measure. This is acknowledged and the need to build an evidence base via sophisticated monitoring and evaluation of rural electrification projects is highlighted.

The World Bank review is generally positive and highlights that in many cases rural electrification can be economically justified and cost recovery tariffs are achievable. Regarding countries with the lowest grid coverage (mainly in sub-Saharan Africa), it is noted that grid expansion costs will mean a slow growth in rural grid connections. Off-grid solutions are offered as an option, however it is suggested that full cost-recovery is unlikely and the long term technical and economic sustainability of these solutions must still be improved.

Excluding South Africa, Africa has the lowest rural access to electricity of any continent, hence many countries in Africa continue to rely heavily on traditional fuels. For example, in Malawi 97% of energy comes from biomass in the form of firewood, charcoal, and agricultural and industrial waste (Karekezi et al., 2003). Only 30% of the 690 million people in sub-Saharan Africa have access to electricity, furthermore, electricity access rates vary considerably from urban areas to rural areas leaving the rural areas with very low access rates (Karekezi et al, 2003, Hammond and Kemausor, 2009). Approximately 7 % of Malawians have access to electricity, of which 30 % live in the urban areas. Only 1 % of the rural population has access to electricity (Govt of Malawi, 2002).

While rural electrification may be a well established need in these countries, simply maintaining the existing grid infrastructure is often the first challenge for the national Government and private sector. National electricity grids are plagued with intermittent power black outs and heavy load shedding programmes (Hammond and Kemausor, 2009). Compounding this issue, demand is increasing at the rate of 4.6% and surplus generation capacity is running out (SADC, 2009).

Incentives for utility companies to address electrification of rural communities are limited due to the capital investment required and the lack of consumers able to pay connection fees and tariffs (Nziramasanga, 2001).

As an alternative to grid expansion, renewable energy sources (especially solar PV systems) have been actively supported in Africa by multilaterals, governments and non-governmental organizations over the last several decades (Bawakyillenuo, 2007). The successes, failures and lessons learnt by such initiatives are summarised by the FAO who report on the application of solar photovoltaic systems for sustainable agriculture and rural development. (FAO, 2000). The authors acknowledge that PV can only meet part of rural energy needs but highlight it's suitability for areas such as health care, education, communication, agriculture, lighting and water supply.
The UNDP have also explored the limitations of PV for decentralised rural electrification and highlight a niche for providing a public service such as school lighting and power, information and communications, water pumping and vaccine refrigeration, thus targeting the whole community (UNDP, 2004).

It is clear that although the challenge of meeting the energy needs of rural African communities is complex and will require a wide portfolio of solutions, PV systems can contribute positively to decentralised rural electrification and are particularly suited to community scale solutions.

2. Introduction

The Malawi Growth and Development Strategy (2007-2011) (Govt of Malawi, 2006) sets out the Government of Malawi's commitment to improving the lives of the rural poor through infrastructure development and economic empowerment. Areas four and five of the six key priority areas are Energy Generation and Supply, and Integrated Rural Development respectively. Both state a specific objective of increasing access to reliable, affordable electricity in rural areas. Integral to this is the acceleration of the Malawi Rural Electrification Programme (MAREP) which highlights the use of solar energy for off grid power supply in rural areas where grid expansion is uneconomical.

Electrical power supply is a key foundation for the economic and social development of rural communities. Access to efficient modern energy supplies has been identified as being vital to aiding the social and economic development of rural communities and also in achieving poverty reduction targets as outlined in the Malawi Vision 2020 (Govt of Malawi, 1998), Malawi National Energy Policy (GoM, 2003) and the World Bank Malawi Country Assistance Strategy 2007-2010 (World Bank, 2007). The importance of electrifying rural areas has also been emphasized in the Malawi Economic Growth Strategy with regards to improving education, employment, and enterprise opportunities.

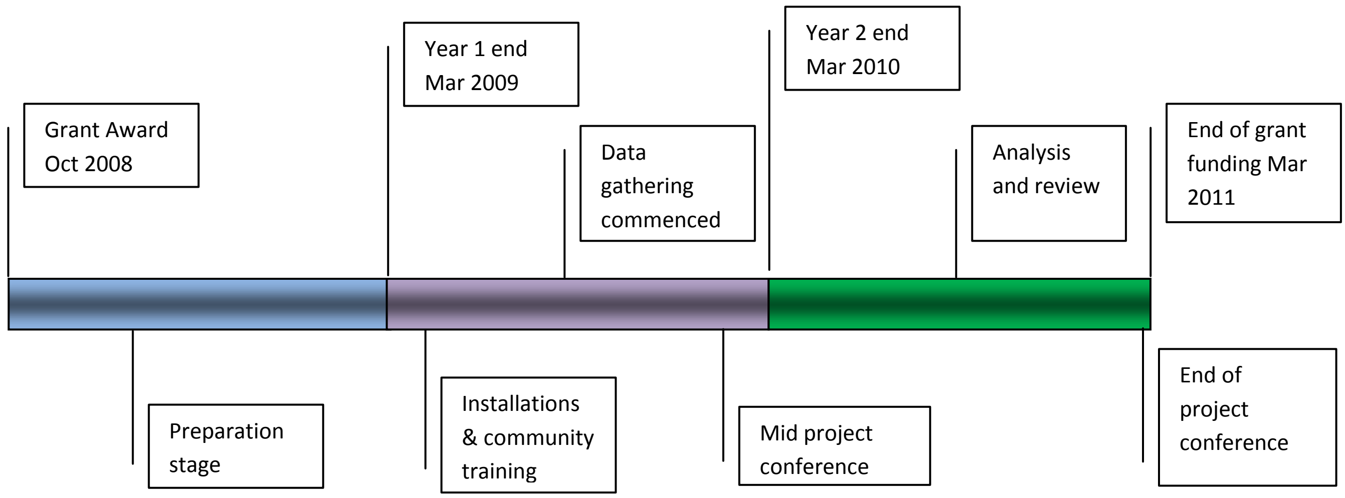
The CRED project is one of three initiatives from the University of Strathclyde's Malawi Millennium Project that have received support from the Scottish Government's International Development Fund. The project arose from a growing interest within the University's Electrical Engineering Department on sustainable solar electricity deployments in the developing world. Initial success and growth of expertise through projects in The Gambia encouraged an ambition to address more of the wider sustainability challenges of solar electricity as well as the technical. The well established links between the University of Strathclyde (UoS) and the University of Malawi Blantyre Polytechnic provided the opportunity to form a partnership that could implement a long term project addressing the sustainability issues that undermine renewable energy solutions in Malawi. As a result, a team of Strathclyde staff visited Malawi in Feb/Mar 2008 and a mixture of one to one meetings and stakeholder workshops were held with government officials (Department of Energy), ESCOM (utility company) staff, representatives from the Malawi Industrial Research and Technology Development Centre (MIRTDC) and academics at the Polytechnic to discuss the most pressing needs relating to renewable energy. The team also met with a number of international organisations including the UNDP, the World Bank, Unicef and DfID in order to understand current and future projects.

A Partnership consisting of staff from the University of Strathclyde, Blantyre Polytechnic (UoM) and the Department of Energy was subsequently formed and the Scottish Government funding granted at the end of October 2008 with the CRED project officially commencing November 2008.

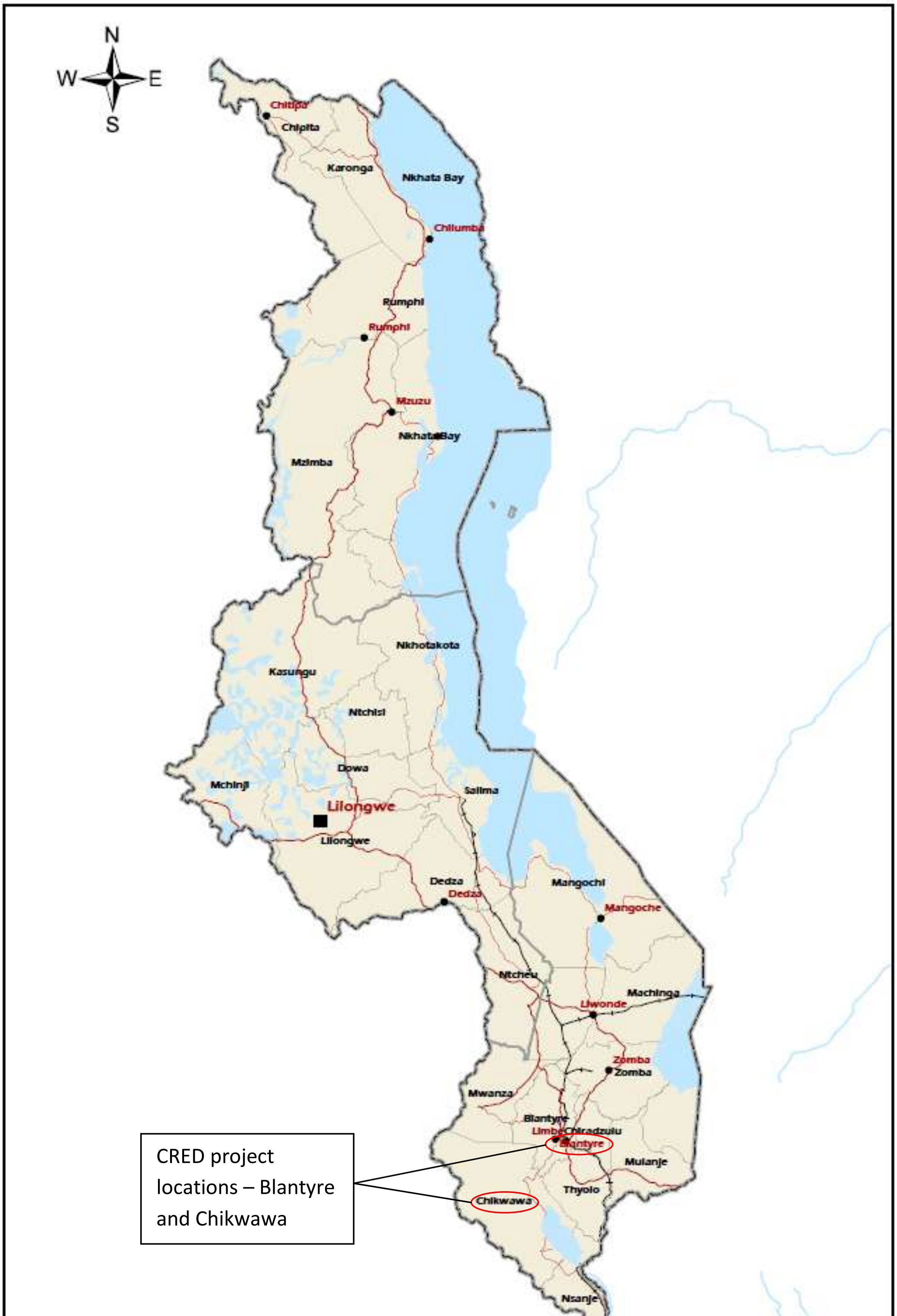
The key principles of the CRED project are to improve the sustainability of rural PV deployments through deployment models focussing on community engagement and empowerment, local responsibility and income generation. Village energy committees backed up by an appropriate support chain of a local field coordinator, local suppliers and local government and academic partners are the foundation of the project.

The following sections of the report describe the project design and implementation. The final chapters set out the data collected during the project, the early conclusions for sustainability, a proposed sustainable deployment model and recommendations for further work.

The major elements of the project are shown in the timeline below.



The location of the project within Malawi is shown on the following map.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Nsanje
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CRED project locations – Blantyre and Chikwawa

3. Preparation Stage

3.1. Project Definition

The CRED project set out to achieve the following goal.

To use a pilot installation of 4 community solar energy systems to establish and demonstrate a best practice sustainable model for rural community social and economic development based around renewable power supplies, microfinance and income generation while building in-country capabilities and partnerships to enable larger scale independent deployment.

The lead up to defining this goal comprised of a detailed review of Government of Malawi policy, the Scotland Malawi Cooperation Agreement and the associated cross-cutting funding themes. Building on previous experience of off-grid PV in The Gambia and a literature review of lessons learnt and best practice regarding rural electrification and off-grid electricity supply in developing countries, the project team identified a renewable energy project that could assist the strategy of the Govt of Malawi.

It is clear that Malawi urgently needs to upgrade and expand the national grid infrastructure and associated large-scale generation. However GoM policy recognises that this can only reach a small proportion of the population in the short to medium term. Off-grid PV has been utilised in Govt programmes to improve remote health facilities and to provide three pilot 'micro-grid' village electricity networks. PV has also been used by many NGO's operating in Malawi. The UNDP and GEF funded a $3.5million project Barrier Removal to Renewable Energy in Malawi in 2002 (UNDP, 2010). This project successfully established institutions for training, standards and certification for the renewable energy industry in Malawi. For PV installations in particular; technician training, a strong base of certified and regulated suppliers, design standards and public awareness have created the foundation for small-scale PV energy to be widely deployed in Malawi.

However, the sustainability of PV installations in Malawi remains in question. There is an oft quoted anecdote that 50% of the installed PV systems in Malawi no longer work. In addition, the use of PV in rural communities also presents a hugely prohibitive capital outlay unless met by Govt or NGO funding.

With large scale infrastructure projects out-with the scope of this type of project, the theme of improved sustainability for community sized renewable energy supplies was identified as an area of importance that would contribute to the progress of increased renewable energy deployment initiated by BARREM and GoM policy.

Two high level project objectives were identified:

- To increase the opportunities for social and economic development through increased access to reliable, affordable electrical energy in rural communities.
- To develop and increase the capacity of key stakeholders to advance GoM off grid rural electrification programme.

Linked outcomes were defined and a program of activities outlined – see Appendix A.

3.2.Project Team

The University of Strathclyde has a long standing relationship with the University of Malawi, Blantyre Polytechnic. In particular, Environmental Health has an established history of successful projects in the areas of Maternal Health, Water and Sanitation under the banner of the Scotland Chikwawa Health Initiative (SCHI). Working in partnership with the existing projects and building on the existing excellent relationships with the Polytechnic was a natural choice for the new energy project. Meetings with the Polytechnic senior management and key Department of Energy personnel identified the project team:

Senior Project Management/Supervision: Graham Ault (UoS), Elijah Banda (UoM)

DoE Support and Guidance: Lewis Mhango, Khumbo Lhungu

Project Management: Kelvin Tembo (UoM), Damien Frame (UoS)

Project Coordinator: Scatter Makumbi (SCHI)

The UoS and UoM project management and delivery team worked under the support and guidance from the Government of Malawi Department of Energy rural electrification team. Mr Makumbi, who is a project coordinator for the SCHI was employed by the project 2.5 days a week to act as the field project coordinator.

3.3.Project Preparation

3.3.1. Community sensitization and Data Gathering

With the project team complete and the project objectives defined, suitable communities for the pilot installations were identified. An initial three communities in Chikwawa district were chosen for the following reasons:

- Existing community presence and working relationships with the SCHI
- The socio-economic status of the area is one of the least developed in Malawi
- The solar resource in Chikwawa is excellent

The communities identified were: Mwanayaya, Namira and Mwalija. A fourth community, peri-urban to Blantyre, was also included. This community, Malavi, were involved with a Scottish primary school twinning initiative that provided funding for an extra installation and provided an opportunity for comparison and further learning to the main project sites in Chikwawa.

During the second year of the project funding from UNESCO allowed a further installation to take place, assisted by a student expedition from University of Strathclyde. A large school in Mikolongo, near the village of Namira, was identified as an appropriate location. During the third year of the project, remaining capital budget was used to undertake installation in a further school in the village of Chingolomo.

The complete list of communities involved in the CRED project is:

- Mwanayaya – School and Health Post
- Namira – Health Post
- Mwalija – Health Post
- Mikolongo – School
- Chingolomo - School
- Malavi – School and Office

Introductions to the identified communities commenced and a programme of sensitization meetings took place and workshops were held to identify energy priorities. These meetings had a formal structure dictated by the community and included Traditional Authorities, group and village headmen, village elders, church elders, and representatives from the health and education sectors. The sensitization meetings introduced the topic of energy use and the suggestion of providing alternative electricity supply in the village using renewable energy. The concept of solar energy was explained using analogies to daily tasks such as water gathering. The idea of solar energy being a limited resource that is gathered each day compared to the more familiar notion of ESCOM (grid) supply of 'unlimited' electricity was a key message.

The community meetings had two main purposes:

- Introduce the project team and explain the concept
- Establish the energy priorities from the perspective of the community

In parallel with the community meetings, random sample questionnaires were used to baseline existing energy usage and existing and potential enterprise schemes that required new energy sources.

From this information gathering exercise, clear energy priorities emerged at a community level and at a household/individual level.

The information gathered on current energy use is summarised in Table 1 below.

Energy Use		Priority	Source	Cost
Cooking	Firewood	High	Local	Medium
	Charcoal	High	Trading Centre	High
Lighting	Paraffin	Med/High	Fuel Station	High
	Candles	Medium	Trading Centre	Medium
	Matches	Medium	Trading Centre	Low
	Torch (Batteries)	Medium	Trading Centre	Medium
Communications	Mobile Phone (Charging)	Med/High	Trading Centre	Medium
	Radio (Batteries)	Medium	Trading Centre	Medium
Social	Video Show	Low	Trading Centre	Low
	Cold Drinks	Low	Trading Centre	Low

Table 1: Energy Use Summary

When asked about energy use, the respondents were asked to grade the priority of the energy using activity within their daily life. They were also asked to grade the cost of the energy using activity in relation to the proportion of the daily household budget. Trading centres and fuel stations are between 5-15km distance from each village.

The information gathered on the perceived benefit of electricity supply is summarised in Table 2 below. Workshops, village gatherings and individuals were asked what kind of facilities or services they thought electricity could provide and the relative importance to the community or to themselves. The frequency with which each benefit was suggested by a respondent is also indicated.

Perceived benefit of electricity		Importance	Frequency
Community	Irrigation	High	High
	Maize Mill	High	Medium
	School lighting	Medium	High
	Health post lighting/fridge	Medium	High
Individual/Household	Cooking	High	High
	Lighting	High	High
	Phone charging	Med/High	High
	TV/radio	Medium	Medium
Business	Barber Shop		High
	Video Show		Medium
	Welding		Low
	Poultry rearing		Low
	Tailoring		Low
	Cold drink sales		High

Table 2: Perceived Benefit of Electricity

The clear priorities of existing energy use were:

- Cooking
- Lighting
- Communications

Being majority maize farming communities, irrigation and flour mills were by far the biggest perceived community benefit of electricity supply.

Further community workshops were held to discuss the capabilities of solar energy and explore the most appropriate focus for the CRED project. The power requirements of irrigation and flour mills require grid supply and are not feasible for standard solar power solutions. Although cooking was the top priority of a household, even with a substantial power supply to a home, purchasing an electric cooker was not a viable option for the vast majority.

Projects addressing sustainable wood fuel supply and district wide agriculture support are in operation in the area and best suited to address these needs.

The CRED project therefore proposed to initially focus on education and health facilities that also provide the wider community with access to lighting and small amounts of AC power. School and health post solar energy installations would provide lighting, refrigeration and mobile phone charging facilities for the community.

3.3.2. Energy Committees

At all stages of initial engagement with the communities, local ownership was emphasised as a basic principle of CRED. The sensitisation workshops stressed that the solar installations were to be community owned resources with the responsibility for managing and maintaining the systems resting with the community themselves. The concept of an Energy Committee was proposed and agreed as the vehicle for community ownership and participation. This would mirror the existing, familiar committee structure used in water, sanitation, health and village development committees.

The following process was agreed for the responsibility and ownership of the systems.

- Design and installation would be managed by the CRED project team and a contracted local supplier. Community consultation would occur throughout. The energy committee would organise local assistance in the form of building materials and labour.
- Training for the energy committee and school and health post staff would be provided by the CRED project team.
- A formal handover ceremony would transfer ownership to the community.
- The energy committee would manage and maintain the system on behalf of the community. Regular energy committee meetings would provide feedback and accountability to the community.

Each village showed a high level of enthusiasm for the project and embarked on energy committee elections with the support of the field coordinator. In each case a 10 member Energy Committee was formed representing the major stakeholders (as identified by the community) e.g. community elders, church elders and teachers. There is a near 50-50 gender and age balance.

3.3.3. System Design

PV system design standards are well established for off-grid solutions and are widely available. These standards describe the various electrical components required and the appropriate sizing, installation and wiring of these components. The registered renewable energy suppliers in Malawi are required to work to these standards and supply international brand products. However the range of products available is limited and the option to choose preferred grade and quality of electrical components is restricted.

Standard PV system design rules were used to calculate the dimensions of the system by the project team in advance of engaging with suppliers.

Standard design components

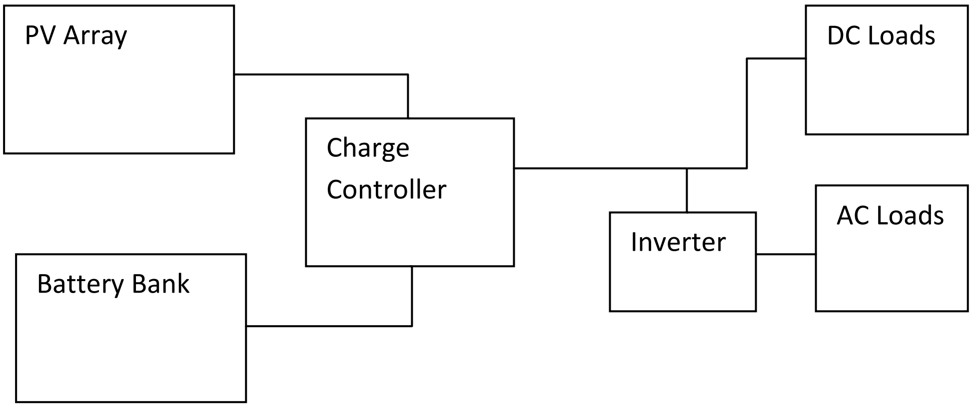


Figure 1: Standard design components

The design process consists of six stages

- Load estimation
- Battery bank sizing
- PV array sizing
- Controller specification
- Inverter specification
- Wiring specification

Additional aspects to the design regarding earthing and protection were also considered and a detailed discussion can be found in the available literature (Solar Energy International, 2004).

Load estimation

The load estimation calculations were based on the following standard approach.

Average daily Watt hours = (Watts) x (Hours of use per day) x (Days used in a week) / (7 days)

An example worksheet for a simple school installation is provided below

		Watts				**Average daily Wh**	
Loads	**Qty**	**AC**	**DC**	**hrs/day**	**days/wk**	**AC**	**DC**
CFL lights	18		9	4	6		555
Sockets - phones	4	5		4	4	46	
Laptop	1	50		3	3	64	

Table 3: Example load estimation

The inverter efficiency should be taken into account and the AC total multiplied by an appropriate factor. E.g. in the example provided a 90% efficiency would leave the average daily AC requirement as 122Wh.

Battery Sizing

The battery bank size is dictated by the load estimation, the days of autonomy (operation in times of poor weather/cloud cover) and the depth of discharge.

A variety of battery technologies are available, however in Malawi the standard available specification is 12V lead-acid deep-cycle.

The calculation for a 12V system is as follows:

Average Amp-hours per day = (Total Average Watt-hours per day) / 12

Number of Batteries = (Average Amp-hours per day) x (days of autonomy) / (discharge limit) /(battery Ah capacity)

Continuing the example provided for 110 Ah batteries with 2 days of autonomy and a 50% discharge limit will result in:

Number of Batteries = (56) x (2) / (0.5) / (110) = 2.03

PV array sizing

The size of the PV array is dictated by the amount of current required and the expected levels of irradiation. The approximate measure of solar radiation is the peak sun hours per day. This is a value that describes the total amount of irradiation from sunrise to sunset by an equivalent number of hours of the sun staying stationary overhead. In Malawi, the peak sun hours per day value is six.

The average daily current requirement is the average amp-hours per day adjusted to account for battery efficiency.

Although PV module sizing is often described in Watts, they are rated by the current output under peak conditions (peak amps).

The PV array sizing calculations are:

Array Peak Amp requirement = (Ave Amp-hours per day) / (battery efficiency) / (peak sun hours per day)

Number of panels = (Array Peak Amp requirement) / (module peak amp rating)

Continuing the example again for PV modules with 5A peak:

Number of panels = (56 / 0.8 / 6) / 5 = 2.33

Controller sizing

The key parameter for the controller is the short circuit current of the Array. This is determined by the number of panels connected in parallel and in our example would be 10 Amps. Typically a 13A charge controller would be chosen.

Inverter Sizing

The size of the Inverter is determined by the AC load required with consideration for surge power. In Malawi 300W or 600W inverters are generally available.

Wiring

In the CRED project, the wiring and general fittings were determined by the PV system supplier, however this was checked against IEE guidelines.

Earthing and Protection

Lightning protection was provided by a casing earth connection, however the systems were not electrically grounded as per standard design recommendations for systems under 50 volts. The inverters included short circuit protection and additional protection was provided by circuit breakers between the battery and PV module wiring.

3.4. Community System Design

Using the standard design recommendations described above, the requirements for each installation were established. The initial designs were used to request quotations from suppliers and final designs were agreed as described in the following sections.

3.4.1. Malavi School

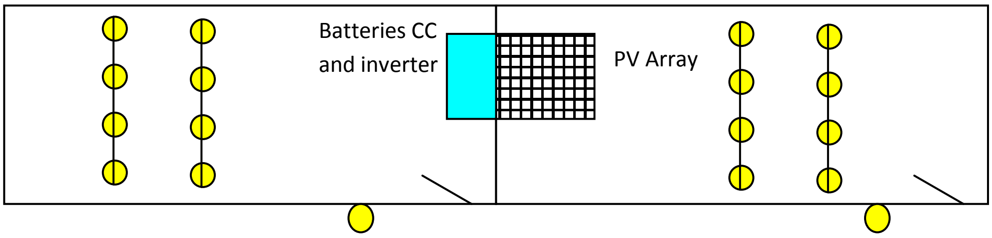
Due to the matched funding available from Malavi's twinned school in Scotland, three installations were undertaken. A school block with lighting and AC power for phone charging, a teachers office with lighting and power for a laptop and a battery charging station where teachers brought their own lead acid batteries for charging.

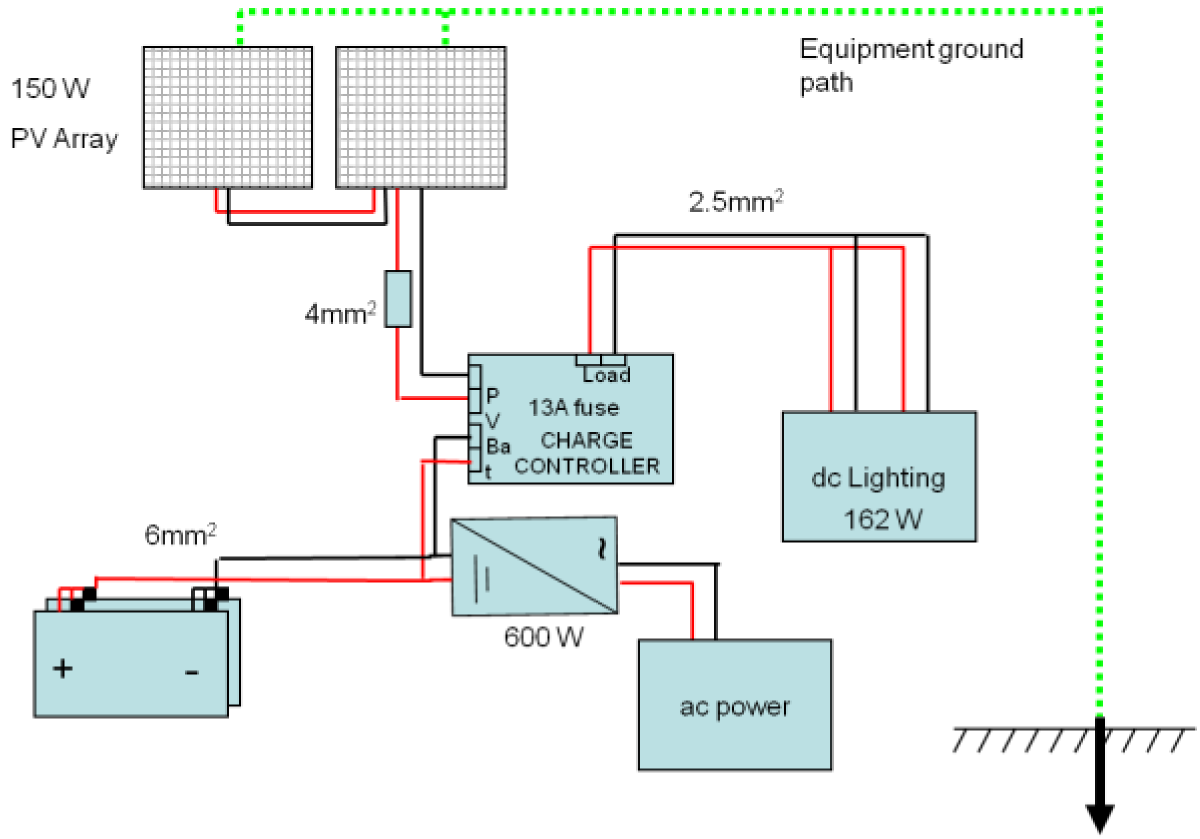
System 1: School Block

The system was designed to run all lighting for 4 hours each evening plus provide AC electricity each day for charging mobile phones and a laptop. The average daily load for this design was 680Wh. Two days of autonomy were also accounted for in the design.

<u>Technical description</u>

- PV Array – 2x 75W panels
- Charge Control – Steca 12Amps
- Batteries – 2x 102Ah Deltec
- Inverter – 600W TES feeding 1 socket
- 18x 11W DC bulbs – 2 rooms each with 8 then 2 security lights



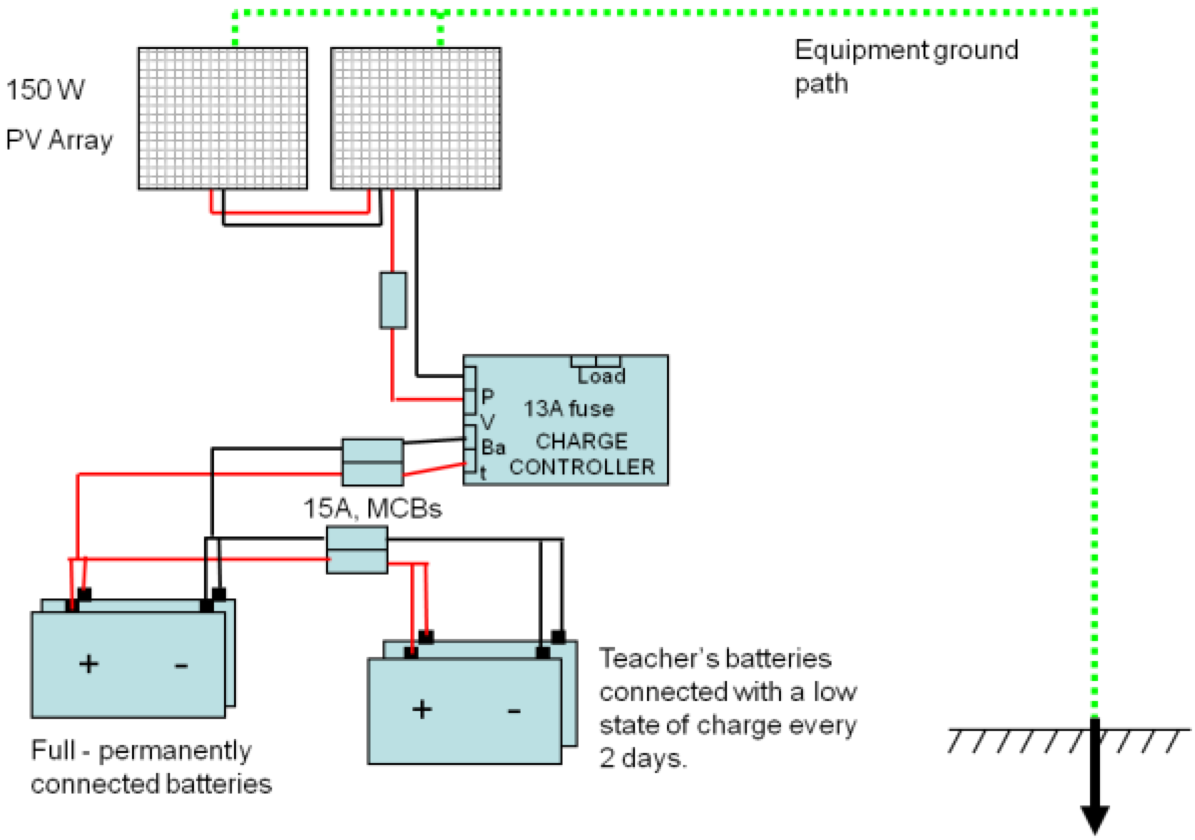


System 2: Battery charging station

This system is also installed at the main block in Malavi. There is no permanent load connected. The Teacher's houses have a simple lighting system of two 9W DC bulbs connected to a 50Ah 12V lead acid battery (600Wh). The average daily load was estimated to be a maximum of 100Wh. An alternating charging schedule sees the teachers bring their battery for charging every two days. The batteries are brought to the charging station and connected in parallel with two permanently connected batteries. The battery bank equalises slowly over time and no damaging currents have been measured. The charge controller senses a low battery bank voltage and applies charge current appropriately from the PV array. It takes approximately one and a half days for the battery bank to achieve full charge.

<u>Technical description</u>

- PV Array – 2x 75W panels
- Charge Control – Steca 12Amps
- 8 x 50Ah batteries in teachers houses. System will charge 2 at a time from a maximum of 50% discharge.



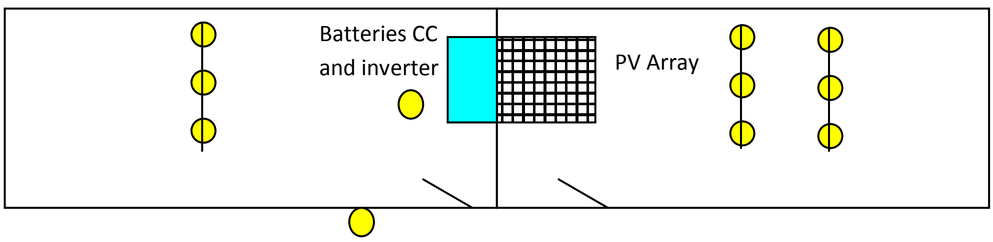
System 3: Teachers Office

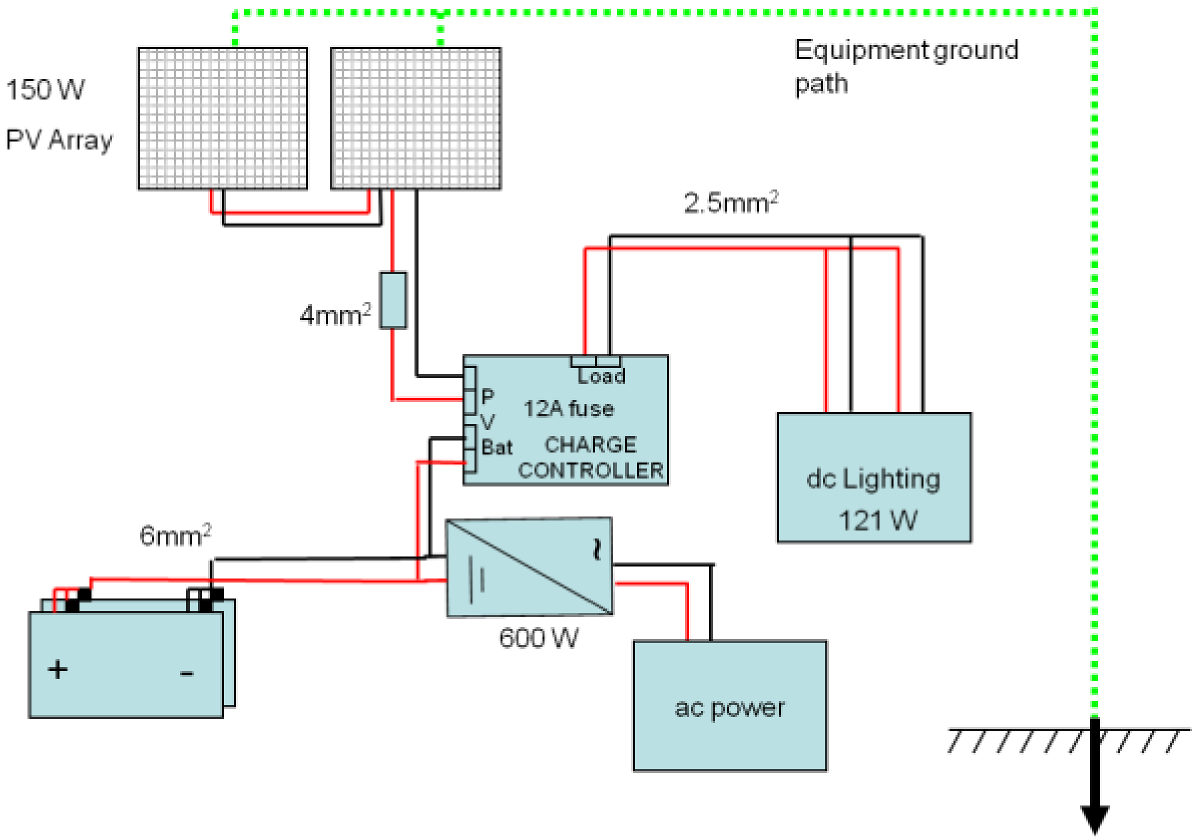
The school twinning program resulted in the building of a new office block at Malavi and also funding for solar electricity. This installation was incorporated into the CRED project.

The system design was very similar to that of the main block described as system1. A lighting and low power AC load comprising of an average 330 Wh/day defined the system sizing.

<u>Technical description</u>

- PV Array – 2x 75W panels
- Charge Control – Steca 12Amps
- Batteries – 2x 102Ah Deltec
- Inverter – 600W TES feeding 1 socket
- 11x 11W DC bulbs – 2 rooms each with 8 then 2 security lights

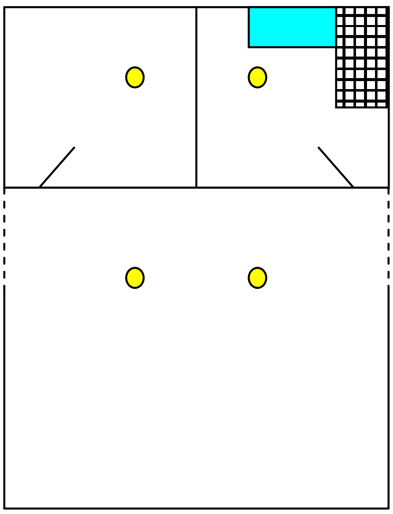




3.4.2. Mwalija

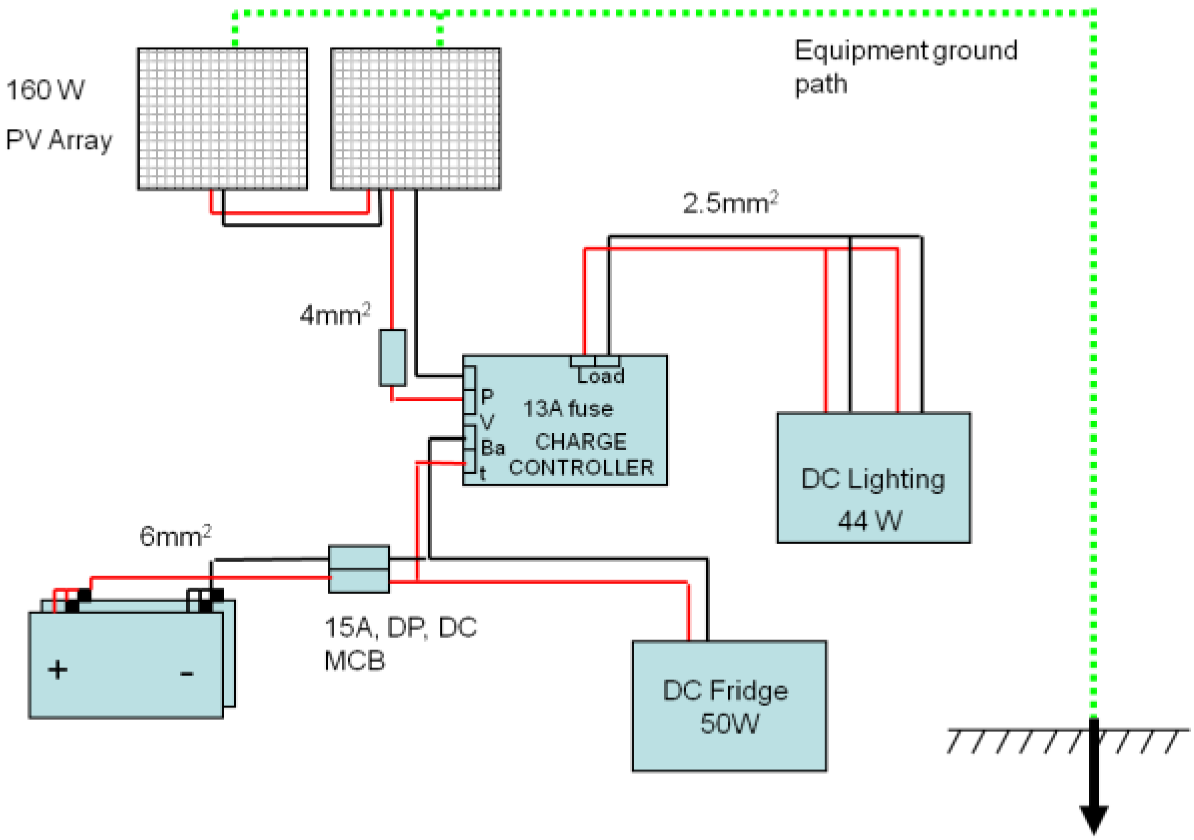
In the village of Mwalija a substantial Health Post building was deemed the most appropriate location for the community system. The system design is based on 178Wh of lighting per day and 400Wh of power supplied to the fridge. 3 days of autonomy were included in the design. The system has been installed in Mwalija Health Post with the fridge, batteries and charge controller located in the Health Worker's office.

Health Post Lighting and Fridge



Technical Description

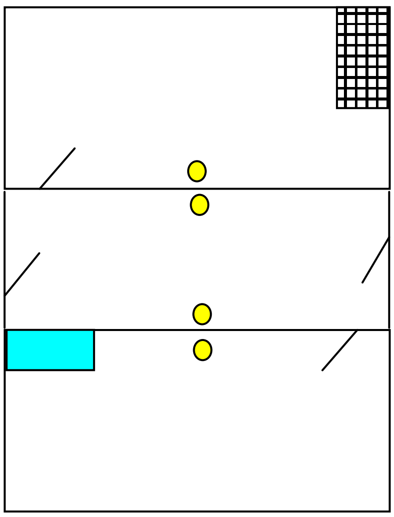
- PV Array - 2 x 80Wp solar PV modules
- Charge Control – Steca 12A
- Batteries – 4 x 96Ah deep cycle
- 4 x 11W,12V energy saver lamps
- Bushmaster 115L fridge made by 'Minus 40'



3.4.3. Namira

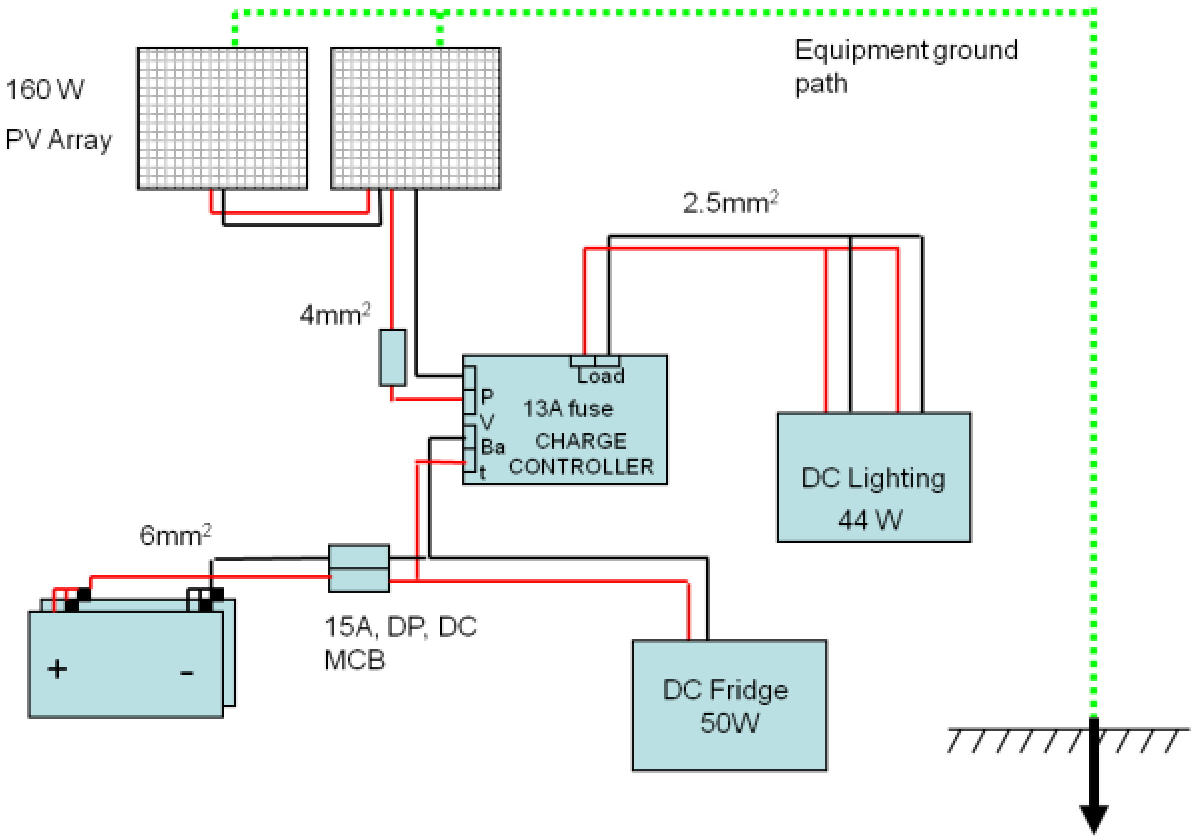
In the village of Namira a substantial Health Post building was again deemed the most appropriate location for the community system. The system design is based on 178Wh of lighting per day (4 hours) and 400Wh of power supplied to the fridge. 3 days of autonomy were included in the design. The system has been installed in Namira Health Post with the fridge, batteries and charge controller located in the Delivery Room.

Health Post Lighting and Fridge



<u>Technical Description</u>

- System Spec: Health Post Lighting and Fridge
- PV Array - 2 x 80Wp solar PV modules
- Charge Control – Steca 12A
- Batteries – 4 x 96Ah deep cycle
- 4 x 11W,12V energy saver lamps
- Bushmaster 115L fridge made by ‘Minus 40’



3.4.4. Mwanayaya

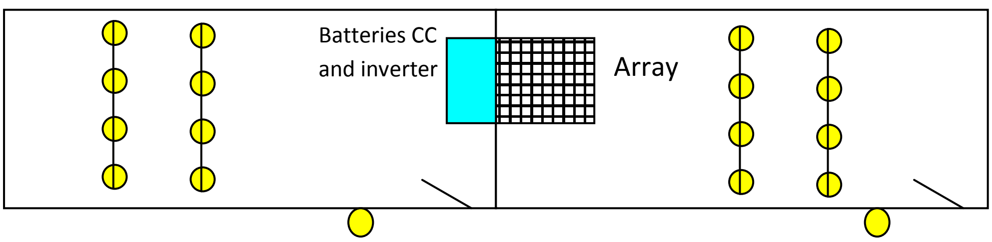
In the village of Mwanyaya a new school building had recently been constructed in addition to the existing Health Post. PV systems for both the school and health post were installed.

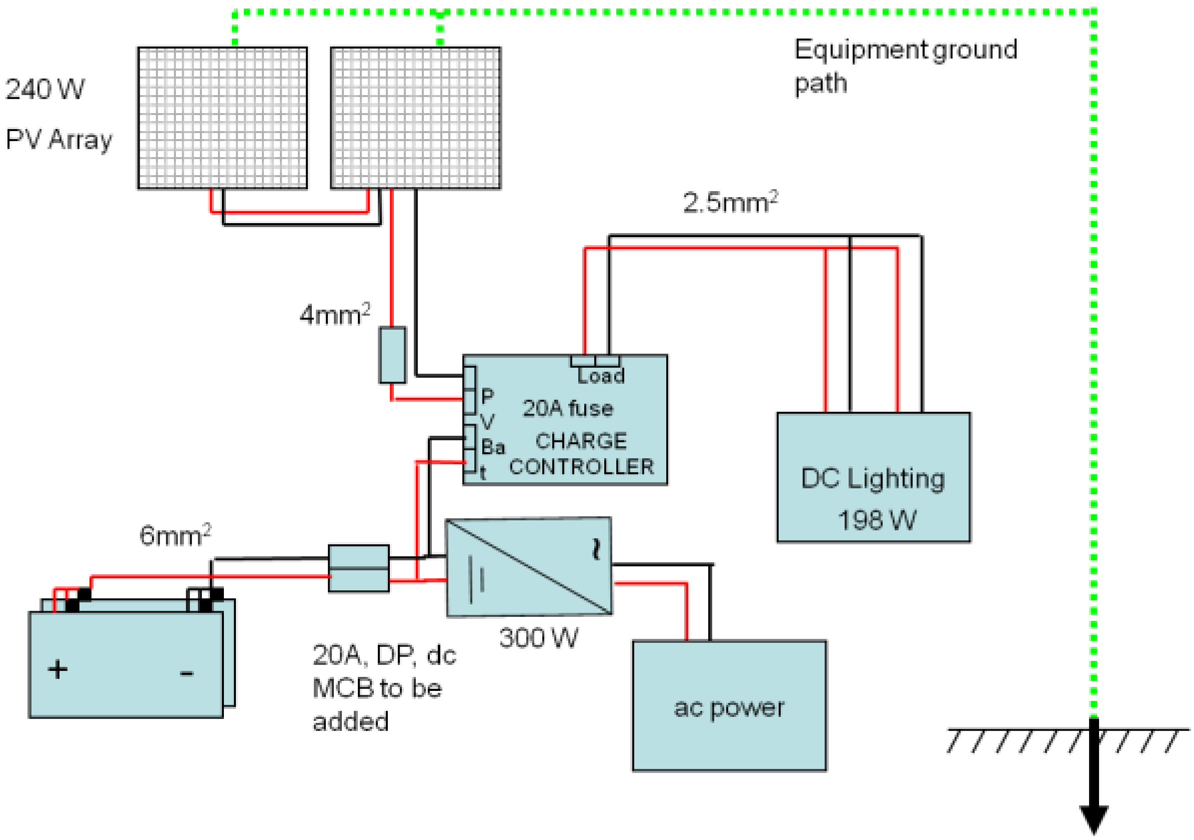
System1: School Block

The system has been designed to run all lighting for 4 hours each evening plus provide AC power for charging mobile phones and a laptop. The average daily load was calculated to be 737Wh. Three days of autonomy are also accounted for in the design.

Technical Description

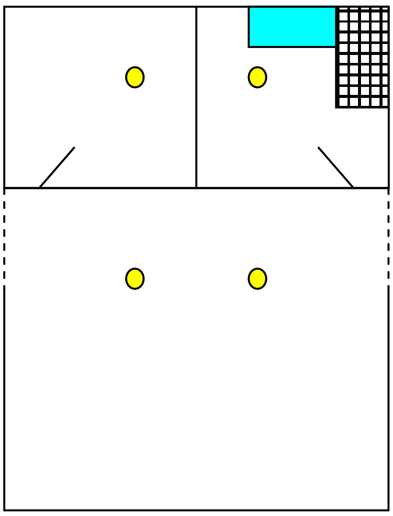
- System 1: School Lighting and Power
- PV Array – 3x 80W panels
- Charge Control – Steca 20 Amps
- Batteries – 6x 100Ah Deltec
- Inverter – 600W TES feeding 1 socket
- 18x 11W DC bulbs – 2 rooms each with 8 then 2 security lights





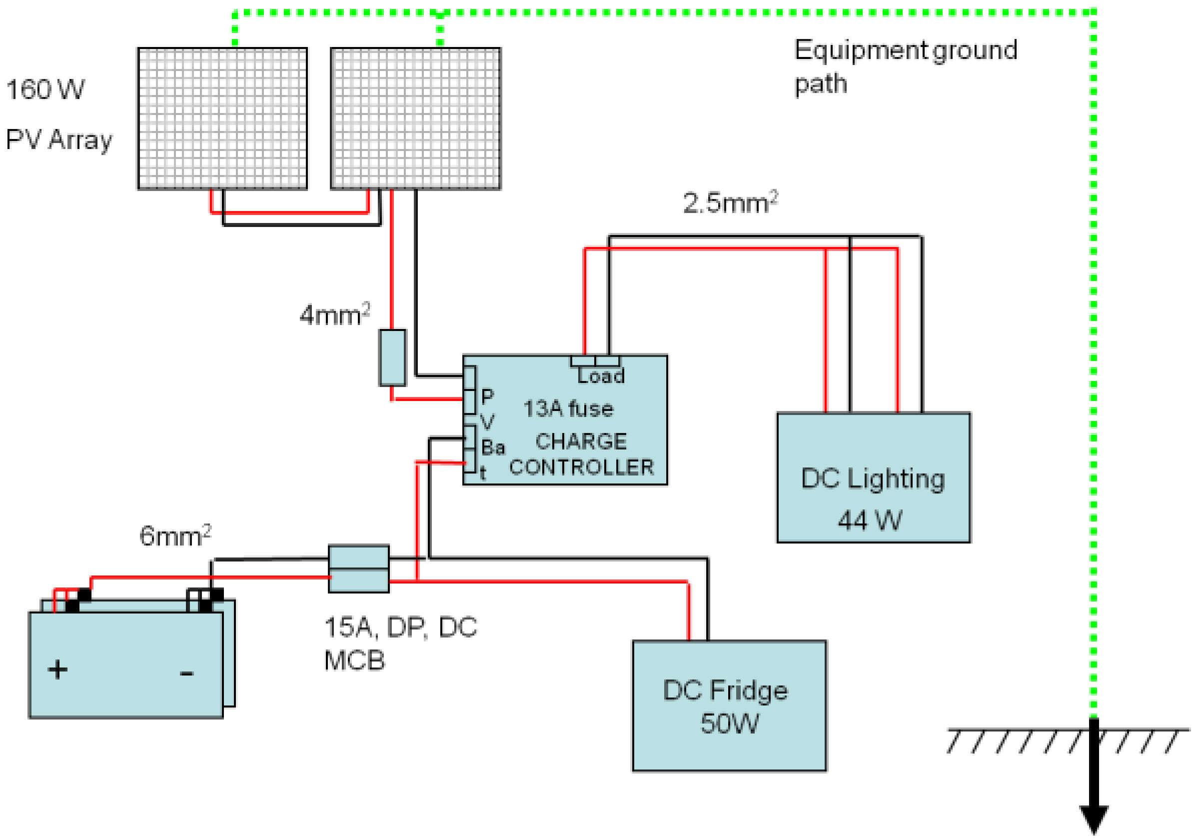
System 2: Health Post

The system design is based on 178Wh of lighting per day and 400Wh of power supplied to the fridge. 3 days of autonomy were included in the design. The system has been installed in Mwanayaya Health Post with the fridge, batteries and charge controller located in the HSA's office.



<u>Technical Description</u>

- PV Array - 2 x 80Wp solar PV modules
- Charge Control – Steca 12A
- Batteries – 4 x 96Ah deep cycle
- 4 x 11W,12V energy saver lamps
- Bushmaster 115L fridge made by 'Minus 40'

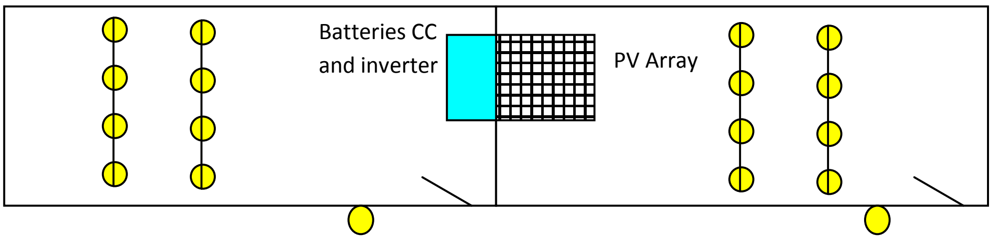


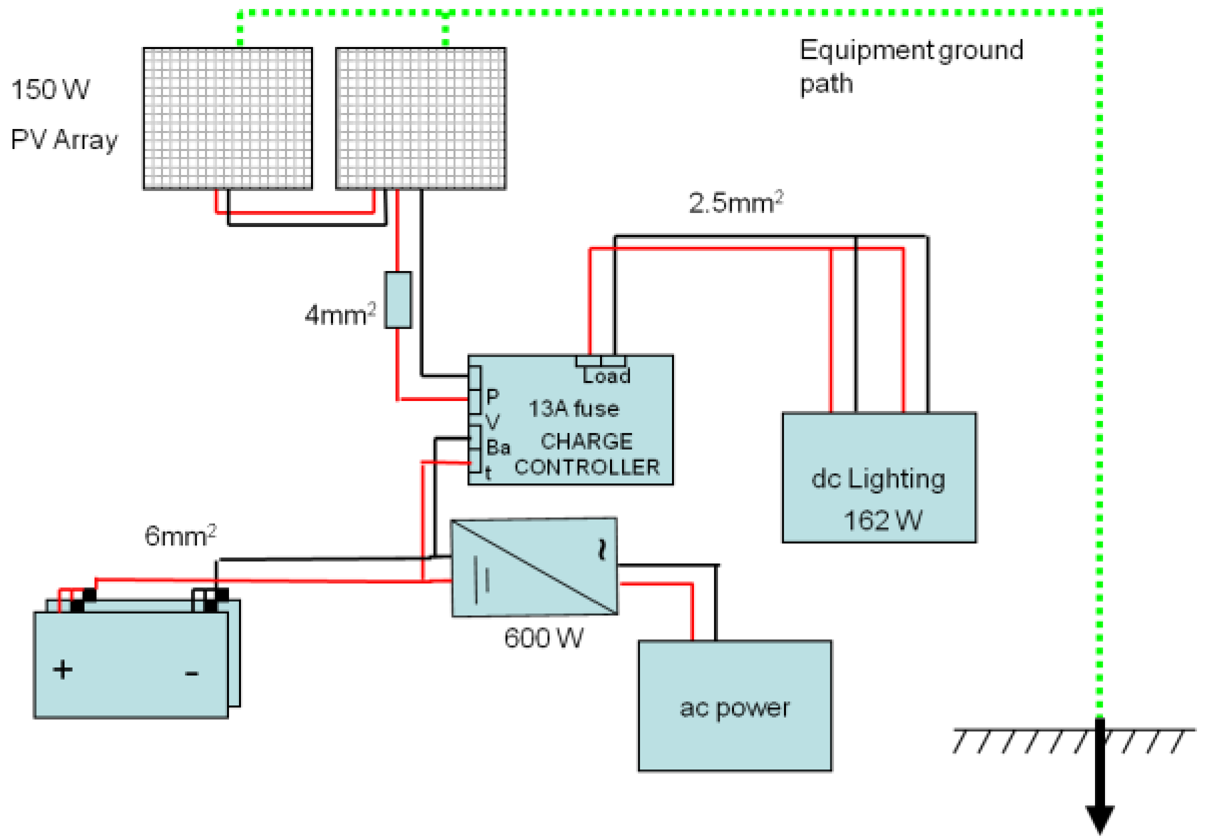
3.4.5. Mikolongo

The system was designed to run all lighting for 4 hours each evening plus provide AC electricity each day for charging mobile phones and a laptop. The average daily load for this design was 680Wh. Two days of autonomy were also accounted for in the design.

<u>Technical description</u>

- PV Array – 2x 75W panels
- Charge Control – Steca 12Amps
- Batteries – 2x 102Ah Deltec
- Inverter – 600W TES feeding 1 socket
- 18x 11W DC bulbs – 2 rooms each with 8 then 2 security lights





3.4.6. Mini Home Systems

The NGO Solar Aid has a strong presence in Malawi (primarily the North, operating out of Mzuzu). The CRED project team made contact with Solar Aid to establish the focus of their work and any opportunities for collaboration. Solar Aid's operations include training and support of entrepreneurial groups for the manufacture and supply of small solar units. These solar units are designed for individual use. They consist of a portable, robust solar panel, rechargeable batteries and an LED lamp. They provide lighting, mobile phone charging and power for a small radio.

During year 2, CRED purchased 50 of these solar units and distributed them to the energy committee members for testing and feedback. The performance and feedback was largely positive and in the latter stages of the project a further batch of 100 mini solar units have been purchased. The intention is for the energy committees to market and sell these systems within the local community as an income generation activity. The cost of each unit is approaching the point where a positive comparison can be made against existing individual spend on paraffin and battery charging. This will be discussed in more detail in later sections.

3.4.7. Year 3 additions

An additional school and health post upgrades were added at the end of year 3. The school installation in the village of Chilongoma follows the same model as Mwanayaya and Mikolongo. An energy committee has been formed and training is scheduled. The Namira and Mwalija health posts were upgraded to allow phone charging via a dc connection (car cigarette lighter model). Issues with fridge cycles and battery damage are currently being investigated at these sites (further information in section 7.2. In partnership with the SCHI a solar powered water pump was installed at Mapelera health post.

4. Implementation Stage

With the preparation stages complete, two parallel implementation activity streams began; system installation and Energy Committee training.

4.1. System Installation

An approved list of PV contractors was provided by Malawian Energy Regulation Authority (MERA). One of the legacies of the UN/GEF project BARREM is that the supply and installation of PV systems is a regulated activity under MERA and design standards have been defined. Several of the accredited contractors were contacted and a mixture of face to face visits and quotations took place to identify best technical capability and price. Quotations were requested for systems as per the above specifications were and a program of installation dates agreed. The project co-ordinator oversaw each installation in conjunction with the energy committees. The energy committees undertook security arrangements such as security bars for doors and windows, night watchmen and/or energy committee security patrol rotas. The construction of small enclosures around the battery banks were organised by the co-ordinator and the energy committees to provide security for batteries, inverters and phones being charged.

After a final inspection by UoS/Poly project managers, the installations were signed off as complete and ownership transferred to the community in a formal handover ceremony.

4.2. Energy Committee training

A 2 day training course for the Energy Committee members was designed and delivered by the Polytechnic. A local administration centre was used to gather all committee members for formal training on electrical theory, health and safety and roles and responsibilities.

Formal and ‘on-the-job’ training was provided for the project co-ordinator regularly throughout the design and installation stages covering the standard energy committee training but in more detail.

Training took the form of very basic energy theory by way of analogy and hands on practical work. Key health and safety messages were delivered. This focussed on lead acid battery safety and the hazards of electrical shock. The basic differences between DC and AC electricity were explained. Training also covered the roles and responsibilities of the Energy Committee and the completion of daily log book records for maintenance, usage and income generation.

4.2.1. Technical training

The technical training course followed the following structure:

- The solar resource
- The principles of solar energy systems
- Solar energy system components
- Solar energy system installation
- Solar energy system applications
- Solar energy system maintenance and safety issues

4.2.2. Health and Safety training

Health and Safety training included:

- AC & DC electricity
  - Differences and associated dangers
- Electric shock
  - Risk of shock
  - Effects of shock
  - Emergency procedure
- Electrical safety
  - Safety precautions
  - Appropriate use
- Battery safety
  - Battery chemistry (hazardous substances)
  - Gassing – requirement for ventilation etc

4.2.3. Roles and Responsibilities training

This training primarily covered the role of the energy committee in the following areas:

- promoting and managing the use of the facilities
  - advertising the availability of lit areas for community use
  - liaising with teachers and encouraging students for evening study
  - ensuring appropriate behaviour of the users

    - ensuring the appropriate use of the system and communicating the capabilities and limitations of solar energy
- maintenance
    - daily check of charge control LEDs – Green, Yellow or Red
    - regular inspection and cleaning of panels
    - regular inspection of wiring for damage – users, termites or animals
- income generation
    - mobile phone charging
    - sale of cold drinks
    - account keeping
    - funding community projects
    - banking funds for future battery replacement

The activities of the energy committee in each of these areas were to be captured in a logbook. The training not only emphasised the type of information that should be collected and why this data was important but also explained the templates for and methods of keeping logbooks.

Examples of the logbook data is provided in the next section.

5. Data Gathering

One of the notable aspects of the project research and design stage was the lack of available data on measurable benefits of rural PV systems. Some economic analysis was available (World Bank, 2008) however most benefit analysis made logical assumptions on the benefits electricity would bring to communities and individuals rather than basing this on measured data. It was deemed essential to record and analyse the actual use of the CRED PV systems as comprehensively as possible.

The energy committee logbooks were the primary record of all activities facilitated by the PV systems. In addition, the CRED project manager Kelvin Tembo undertook an MPhil study programme during the project. Mr Tembo's studies were focussed on the sustainability question of off-grid community PV systems. As well as wider sustainability issues, this work considered some technical aspects and as such, monitoring systems were installed at Mikolongo and Malavi Schools. These systems recorded solar irradiation and system electrical parameters.

5.1. Community Data

Data gathering was emphasised as a vital component of the project with the role of the energy committee vital to success.

The process for data gathering was:

- daily logbook completion by the energy committee
- coordinator gathers logbook records during fortnightly meetings
- coordinator provides monthly reports to project management
- project management accumulate and analyse data

Each committee had logbooks recording data as per the examples below.

Date	Charge Control	Panel Inspection	Wiring Check
10/09/10	Green	Okay	Okay
11/09/10	Green	Okay	Okay
12/09/10	Yellow	Okay	Okay
13/09/10	Green	Okay	Okay
14/09/10	Green	Okay	Okay
15/09/10	Green	Okay	Okay
16/09/10	Green	Okay	Okay
17/09/10	Green	Okay	Okay

Table 4: Maintenance logbook

Date	Community Groups		Students	
	Group	Numbers	Numbers	Hours of study
10/09/10	Choir	40		
11/09/10	Water Committee	10		
12/09/10			25	2
13/09/10			46	3
14/09/10			34	3
15/09/10			40	2
16/09/10	Youth Group	20		
17/09/10	Church Elders	15		

Table 5: System use logbook

Date	Phone Charging		Cold drinks	
	Number Charged	Kwacha	Drinks sold	Kwacha
10/09/10	10	400	0	
11/09/10	9	360	5	100
12/09/10	10	400	4	80
13/09/10	5	200	1	20
14/09/10	8	320	0	
15/09/10	10	400	0	
16/09/10	7	280	4	80
17/09/10	9	360	0	

Table 6: Income generation logbook

The monthly reports submitted to project management provide the following monthly summary.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
DATE 31/12/2010												
ATTENDANCE	10	10	10	10	10	10	10	10	10	10	10	10
MAINTENANCE												
Charge control status	Green	None	None	Green	Green	Green	Green	Green	Green	Green	Green	Green
Panel inspection	Twice	None	None	Twice	Twice	Twice	Twice	Twice	Twice	Once	Once	Once
Wire inspection	Twice	None	None	Twice	Twice	Twice	Twice	Twice	Once	Once	Once	Once
INCOME GENERATION												
Number of phones charged	118	95	90	80	59	71	220	103	107	361	361	536
Cash raised from charging phones	3100	1900	1760	1620	1200	1420	2040	2060	2140	7220	10280	10720
Cash raised from selling drinks	0	0	0	0	0	0	0	0	0	0	0	400
EXPENDITURE												
Room rent	0	0	0	0	0	0	0	0	0	0	0	0
OTHERS												
COMMUNITY ACTIVITIES												
Number of days for students' studies	24	23	19	22	23	13	18	19	20	15	17	9
Number of students attended studies	150	147	125	196	207	163	134	219	123	93	100	60
Number of hours for studies	1-3	1-4	1-4	1-4	1-4	1-3	1-3	1-3	1-3	1-3	1-3	1-3
COMMUNITY GROUPS												
Number of groups attended evenings	7	5	10	8	8	3	12	3	4	3	4	6
Names of groups and attendance												
Football	20	0	240	62	373	109	88	166	112	96	0	25
Youth club	0	0	0	0	0	0	0	0	0	0	22	0
Solar committee	22	11	0	0	0	21	0	42	25	0	22	0
VDC	0	0	0	0	0	0	0	0	0	0	0	0
ASCA	0	0	0	0	0	0	0	0	0	0	0	0
Church	270	16	293	0	0	383	243	50	108	102	242	155
Water Committee	0	0	0	0	0	0	0	0	0	0	0	31
Teachers	0	0	0	0	0	0	27	17	22	16	32	81
SECURITY ISSUES: One person on duty every night												

Table 7: Monthly reports

	Sale of Cold Drinks				Phone Service			
	Money Invested MK	Money Spent MK	Total Sales MK	Net Profit MK	Income From Charging Phones MK	Cash in Hand MK	Money Put in Bank MK	Bank Balance MK
Jan					3,100	3,100.00	8,500.00	8,500.00
Feb					1,900	5,000.00		
Mar					1,760	6,760.00		
Apr					1,620	8,380.00		
May					1,200	9,580.00		
Jun					1,420	11,000.00	3,000.00	11,500.00
Jul					2,040	10,040.00		
Aug					2,060	12,100.00	2,000.00	13,500.00
Sep					2,140	12,240.00	2,000.00	15,500.00
Oct		830.00	1,200.00	370.00	7,220	19,830.00		
Nov					10,280	30,110.00		
Dec				400.00	10,720	**41,230.00**	2,000.00	17,500

Table 8: Monthly Reports

5.2. Technical Data

Technical data is being recorded at the Malavi and Mikolongo School installations.

Solar irradiance (W/m^2) is logged at 15 min intervals using a Micro Circuit Labs SDL-1 Solar Data Logger. An example month and day are shown below.

The currents, voltage and battery state of charge of the systems are also monitored using the Steca Tarcom and Tarom data logger. Examples are shown in Figures 2, 3 and 4 below.

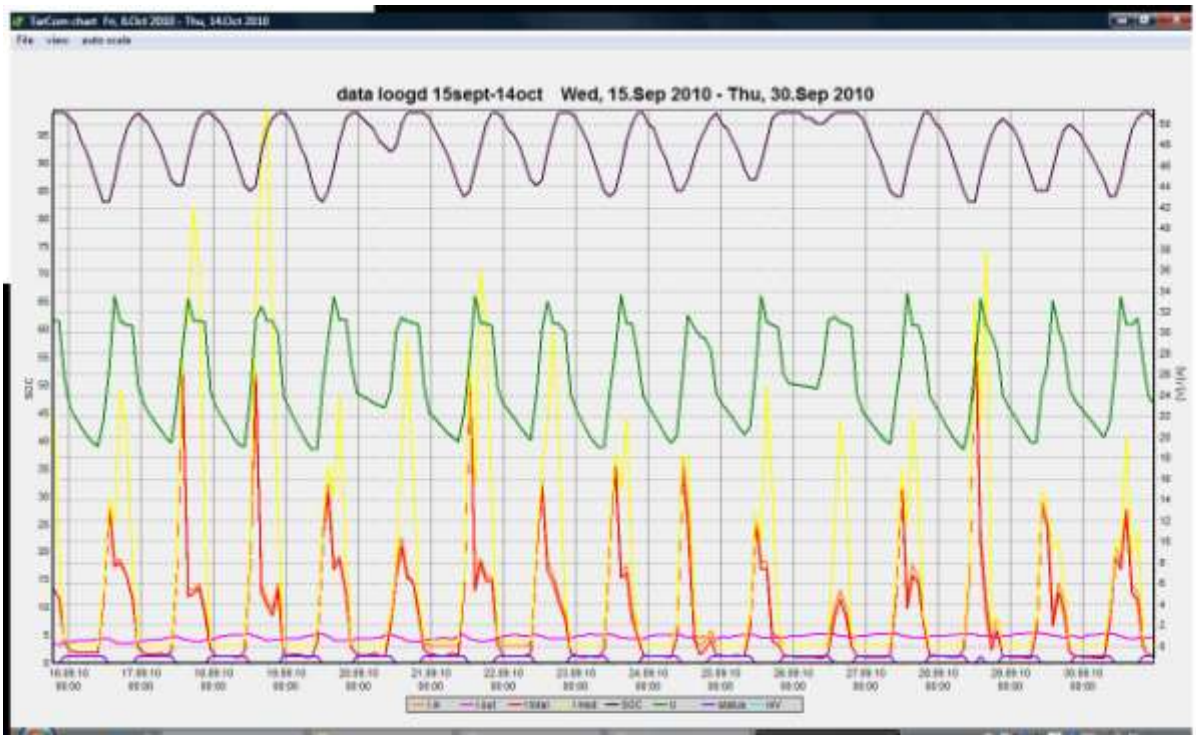


Figure2: Electrical Data

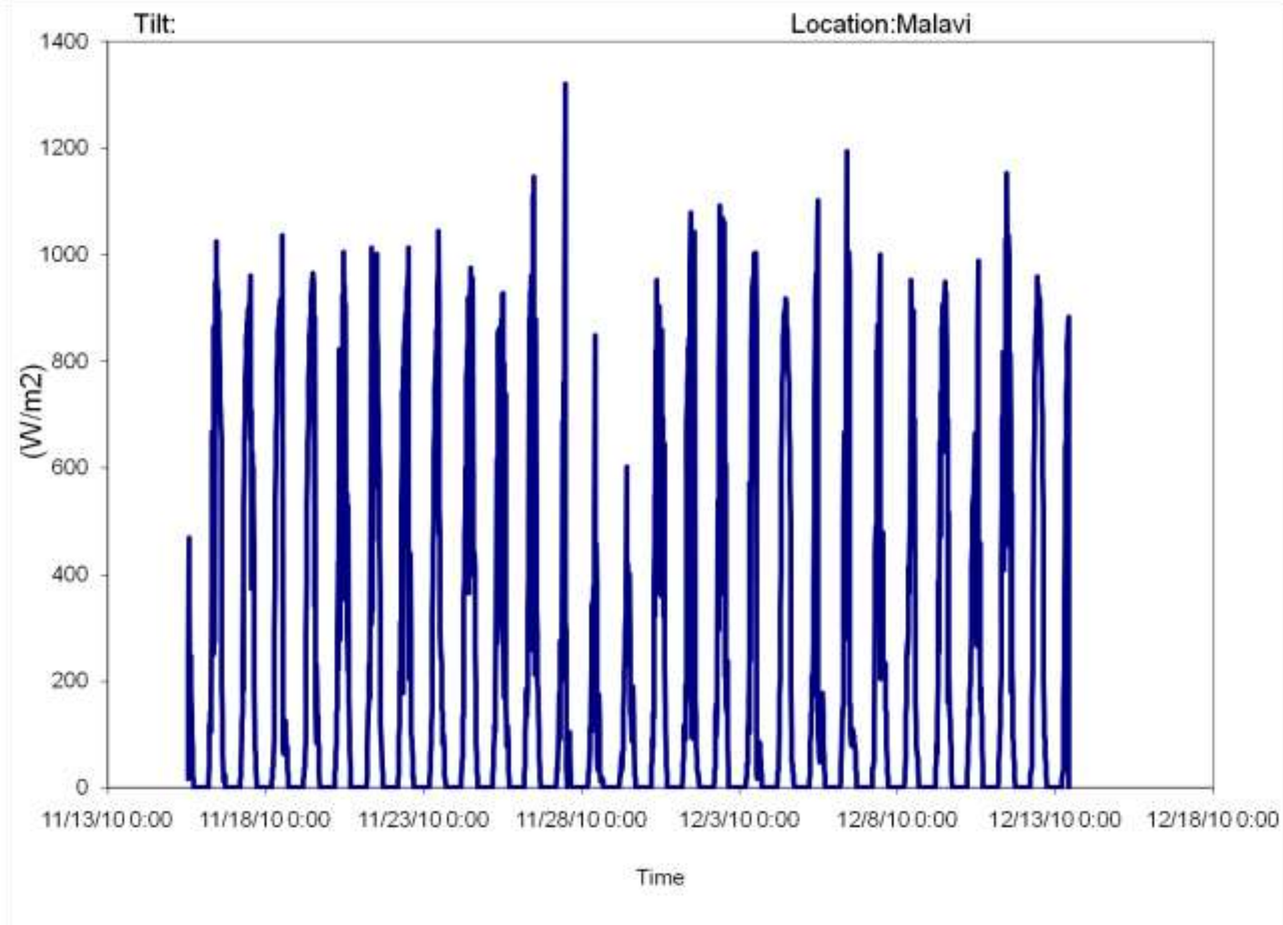


Figure 3: Monthly irradiation data

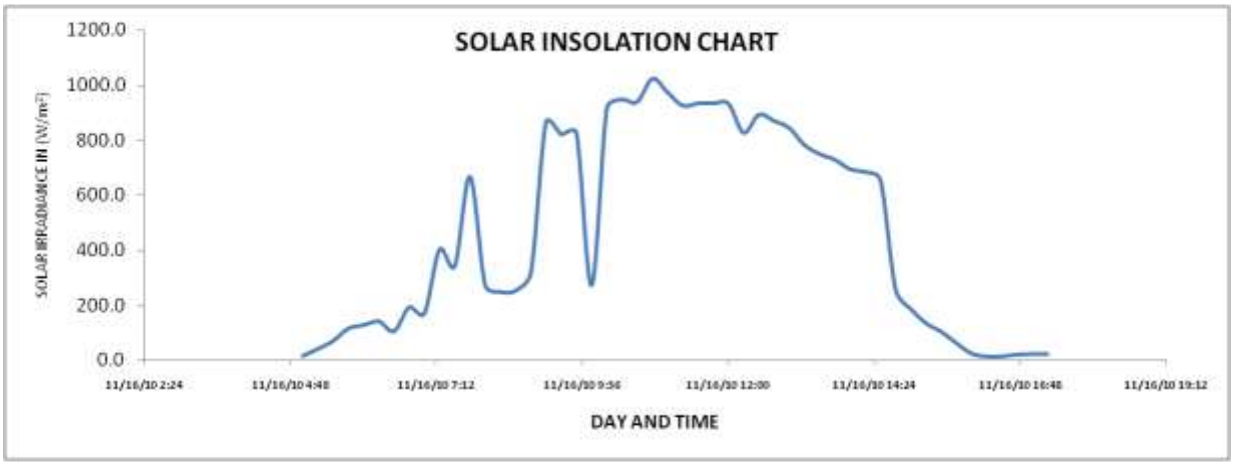


Figure 4: Daily irradiation data

6. Stakeholder Involvement

To facilitate networking and knowledge sharing in the area of off-grid renewable energy in Malawi and to disseminate the CRED project results, a workshop titled "Scotland Malawi Cooperation Agreement - Energy Workshop" was held at Sunbird Capital Hotel, Lilongwe on Monday 4th April 2011. In addition to the motivation from the CRED project to facilitate such an event, additional impetus and support was provided by the Scottish and Malawian Governments following positive discussions at the Cancun climate change conference. The structure and content of this workshop was also informed by a previous min-conference facilitated by CRED at Blantyre Polytechnic in Year 2 of the project.

Attendees:

- Isaac Dambula: Govt of Malawi
- Grace Gondwe: Govt of Malawi - *gondwe.g@gmail.com*
- Khumbolawo Lungu: Govt of Malawi (DoE) – *khumbolungu@yahoo.com*
- Joseph Kalowekamu: Govt of Malawi (DoE) – *jkalowek@gmail.com*
- Zione Ntaba: MERA – *zntaba@meramalawi.mw*
- Arthur Wengawenga: MERA – *awengawenga@meramalawi.mw*
- Wilfred Kasakula: MERA – *wkasakula@meramalawi.mw*
- Harriet Chiwaula: MERA – *hchiwaula@meramalawi.mw*
- Vincent Gondwe: MuREA – *vvgondwe2002@yahoo.com*
- Michael Murenga: LCD – *mmulenga@lcdmalawi.org*
- Alice Chingomo: LCD – *alice.chingoma@lcdmalawi.org*

- Jack Nyirenda: University of Malawi (Polytechnic) – *jack.nyirenda@gmail.com*
- Kelvin Tembo: University of Malawi (Polytechnic) – *kelvinmbizi@googlemail.com*
- Mayamika Nkoloma: University of Malawi (Polytechnic) – *mnkoloma@gmail.com*
- Esther Phiri: University of Malawi (Polytechnic) – *ephiri@poly.ac.mw*
- Kondwani Gondwe: Mzuzu University – *kondwanithapasila@yahoo.com*
- Collen Zalengera : Mzuzu University – *czalengera@yahoo.com*
- Arnold Juma: Mzuzu University – *arnj@mzuni.ac.mw*
- Rona MacKay: Community Energy Scotland - *rona.mackay@communityenergyscotland.org.uk*
- Melanie MacRae: Community Energy Scotland - *melanie.macrae@communityenergyscotland.org.uk*
- Damien Frame: University of Strathclyde – *damien.frame@eee.strath.ac.uk*
- Graham Ault: University of Strathclyde – *g.ault@eee.strath.ac.uk*

<u>Presentations:</u>

- Overview of Government of Malawi Energy Policy - Khumbolawo Lungu
- Scotland's clean energy development - Colin Imrie – In absentia
- Sustainable community energy development solutions and solar power in Malawi - Kelvin Tembo
- Renewable Energy Monitoring System - Mayamiko Nkoloma
- Sustainable community energy development in Scotland – Rona MacKay and Melanie MacRae
- Renewable Energy Technologies for Community Energy - Collen Zalengera
- Community Energy Solutions - Biomass - Kondwani Gondwe
- Community Energy case study (Mulanje Renewable Energy Association) - Vincent Gondwe
- Community Energy case study (Link Community Development) - Michael Mulenga

<u>Discussion topics:</u>

- Policy and Strategy
- Wind energy – resource mapping
- Micro hydro
- Scaling up the current biomass programs
- Comprehensive roadmap for renewable energy
- The role of consultancy in the energy sector
- Networking and information availability
- Manufacture and fabrication of renewable energy technology in Malawi
- Carbon issues
- Models of sustainable community energy development
- Monitoring programmes
- Priority areas for renewable energy development

The outcomes and future work identified in the workshop were disseminated amongst all attendees and relevant Malawian and Scottish Government stakeholders. Further information can be found at www.strath.ac.uk/eee/credproject

It is clear that the existing capability and appetite for further progress in off-grid (and grid connected) renewable energy provides a good base for future partnerships in this area.

7. Analysis

7.1. Data

At the time of writing, CRED has accumulated 22 months of data summarised in the Tables 9 and 10 below.

Community	**Income (MK)**	**Study Nights**	**Total students**	**Community groups**	**Average attendance**
Namira	20483	119	1089	153	24
Mwalija	5479	210	4326	47	12
Mwanayaya	104843	421	2990	121	107
Mikolongo	24055	421	8797	7	11
Malavi	60540	317	240	n/a	n/a
TOTALS	**215400**	**1488**	**17442**	**328**	**38**

Table 9: Community Data

Additional Data	
Income in pounds	862
Light hours	5448
Light Wh	834306
Student hours	52326
Number of phones	6845
Phone Wh	85566

Table 10: Summary of additional data

Income is the total earnings in Malawian Kwacha taken from mobile phone charging and cold drink sales. ***Study nights*** are the number of evenings where students have used the facilities to study. The ***total students*** column shows the total number of students recorded as having been in attendance on these nights. ***Community groups*** is the number of evenings where community groups have used the facilities. ***Average attendance*** refers to the numbers involved with the community groups. ***Light hours*** refer to the number of evenings the facilities have been used multiplied by the amount of hours lighting was used for that evening (average of 3 used in calculation). ***Light Wh*** is the accumulated Watt Hours of electrical energy that has been used for lighting (calculated using recorded hours of use, number of bulbs and 11W bulb rating). ***Student hours*** refers to the total number of students recorded as having spent an evening studying in the facilities multiplied by the time in hours they studied per evening. ***Number of phones*** is the total number of phones charged and ***Phone Wh*** is an approximate calculation of the total energy used for phone charging (nominal 5W rating and 2.5h charge time assumed).

Some highlights from this data are:

- 834.3kWh of energy used by the communities for lighting that facilitates studying and community group activity
- 85.6kWh of energy used for charging phones
- 5448 hours of usefully lit rooms
- Over 17,000 recorded instances of a student using the facilities (this number does not describe 15,000 individuals, clearly many students have been using facilities on a regular basis)
- 52326 hours of student study time
- 6845 phones charged

The data for shows regular use by high numbers of students for evening study. Community groups are using the facilities regularly and security and maintenance responsibilities are being met by the energy committee. Income generation levels are excellent, particularly where there is a mobile phone charging facility. In addition to the regular income, a good savings pattern has been established at Mwanayaya with MK20,000 now banked in an Energy Committee account on behalf of the community.

At various stages in these 22 months issues in the quality of data reporting have been encountered and rectified. Primarily these issues centred on the accounting entries for income generation. The accounting for earned income was in the main captured correctly. However figures recorded were often gross values with the expenditure (for example on cold drink stock or travel) omitted. Close supervision by the project coordinator and some top up training, improved the quality over time. Large expenditures on community projects or bank deposits were almost always recorded and along with the information on the current 'cash in hand' balance, the net income for any dubious months could be calculated in retrospect with sufficient accuracy.

7.2. Technical Issues

Given the unforgiving environment, one of the anticipated risks of the project was technical equipment failure. Although some technical issues have arisen in the course of the project, these have been relatively minor and quickly rectified. The root cause of the issues encountered can be grouped into the following categories: system misuse, environment, system design.

System misuse: The two major technical failures have been serious damage to the charge control and inverter electronics at Mikolongo and battery issues at Namira and Mwalija. The damage at Mikolongo was due to serious overloading of the AC circuit. The exact cause remains unknown, however likely causes include a TV or sound system being used by teachers or visitors to the school. Surprisingly, the Mikolongo energy committee contained the highest number of well educated members who may have been expected to fully appreciate the training provided on appropriate system use and basic do's and don'ts. It is possible that a more advanced understanding of the technology led to misplaced confidence in using the system for new purposes. The battery issues at Namira and Mwalija are believed to be caused by regular over-work of the fridge. Regular opening and closing of the fridge for cold drink sales, especially in the rainy season has resulted in the fridges operating in excess of the design spec. Examination of the logbooks shows that sporadic episodes of low battery state of charge have been recorded during the rainy season indicating that on days of low sunshine the fridges are draining the batteries far quicker than the days of autonomy calculation included in the system design.

Of the two issues described above, only one is deliberate system misuse. The appropriate use of the fridge units was not clear from the manufacturer's guidelines and is a good example of the difference between theoretical equipment performance and practical real life operation.

Environment: Low energy, DC, Compact Fluorescent bulbs are the recommended lamp for solar lighting systems. The type used in our installations were manufactured in Europe by leading solar energy companies. However, a high turn-over of CFL bulbs was an issue for the project. On average, each installation have had to replace about one third of their bulbs in the 2 years of operation to date. The limited availability and cost of these bulbs (£15) is a major challenge for the energy committee even with the support of the CRED team. The previously mentioned fridge issue is also an environmental issue as the extreme temperatures experienced in Chikwawa contribute strongly to the workload placed on the fridge.

System Design: The battery charging station at Malawi school encountered some issues with poor battery levels around 6 months after installation. The root cause of this problem was over discharge when the batteries were in the teacher's homes and also damaged connection cables at the charging point. The problems were resolved by replacing the damaged cables and encouraging the teachers to charge their batteries at regular intervals and not wait until they were completely empty. An improved system design that included robust 'plug and play' connections, an improved dual-bank charge controller and perhaps even individual charge control electronics on the portable batteries would be advisable. In addition, the fridge issue could also be addressed via improved system design. An improved design would include separating the system into two. One circuit would have a charge controller and a battery bank supplying the lighting system the other circuit would also have a charge controller and a battery bank supplying the fridge. Both circuits would be supplied by the same panel configuration.

7.3. Social Issues

The CRED project design recognised that all too often, engineering projects in developing countries focus primarily on the technology and do not consider the complex social interactions that the success of technical interventions relies on. Social scientists from fields such as Social Development and International Development have designed a variety of frameworks and approaches aimed at successful intervention in developing countries.

It appears that there is a lack of available literature demonstrating the integration of social development frameworks with the design, monitoring and evaluation of technical interventions.

While the CRED approach of local committees and field coordinator support has been influenced by existing successful NGO approaches in the areas of health, sanitation, water and education, it is acknowledged that more work will be required to establish the most appropriate methods of achieving full local ownership and participation with a renewable energy installation.

During the latter stages of the CRED project, an independent social science consultant was commissioned to undertake an assessment of the local ownership and participation regarding CRED in the village of Mwanayaya. The findings and recommendations are summarised below.

Summary of findings

- Non- energy committee stakeholders perceive that the energy committee work well as a team and perform their maintenance and practical duties in a competent manner.
- Majority of stakeholders perceive the field coordinator to hold overall decision making power.
- Majority stakeholders perceive the HSA to be the 'key holder' and hold responsibility for making day to day decisions about use and practicalities (such as maintenance and rotas).
- All stakeholders perceive the students to be the primary beneficiaries of the solar installations.
- Majority of stakeholders want 'upgrades': barber shop, extra charging capacity and adult learning facilities.
- All stakeholders see the main duties of the energy committee as maintenance, practicalities and banking of funds.
- Majority of the stakeholders do not perceive solar to be the most important community energy need (cooking and irrigation).
- Majority of the stakeholders do not perceive themselves to have ownership of the solar project (only HSA and to a lesser extent the Energy Committee)
- All stakeholders out with the energy committee have low levels of participation. Members of the energy committee have a 'functional participatory' role.
- All 6 stakeholders/groups unanimously highlight the increased hours of evening study for the students is the primary benefit that the solar installation brings to Mwanayaya.

Recommendations

- Increase communication between school committee – energy committee – health committee and other community stakeholders and develop a more participatory decision making process.
- Process of election or rotation for energy committee to avoid entrenched power and authority.
- Platform/forum for participatory discussion and decision making from all facets of the community
- Continued capacity building of energy committee and gradual reduction of reliance on field coordinator for direction.
- Implementation of a transparent accountability process and increased awareness amongst wider stakeholder of the requirement for maintenance funds

Although the findings are limited by the time and resource available to the study and a more in-depth stakeholder consultation including all CRED communities would have been desirable, the initial results indicate that the CRED approach has partly achieved its goals of local ownership and participation via the vehicle of energy committees and field coordinator support. Whilst the mere presence of community sensitization, training and energy committees in the project design is a step forward for PV installations, the process of increasing community participation, ownership and decision making, ensuring accountability and transparency and avoiding power struggles requires further analysis from a social development perspective for renewable energy installations.

One robust framework from which to assess the social impacts of CRED is the Sustainable Livelihoods Framework. The independent analysis of CRED with respect to the SLF is provided below.

<u>CRED Benefits and a Sustainable Livelihoods Framework</u>

The sustainable livelihoods approach is a valuable approach to foster sustainability of community based projects: "The sustainable livelihoods framework presents the main factors that affect people's livelihoods, and typical relationships between these. It can be used in both planning new development activities and assessing the contribution to livelihood sustainability made by existing activities" (DFID, 1999, pp.2.2), the main factors presented in the framework are:

Human Capital: "the skills, knowledge, ability to labour and good health that together enable people to pursue different livelihood strategies and achieve their livelihood objectives" (ibid, pp.2.3.1)

Social Capital: "social networks upon which people draw in pursuit of livelihood objectives" (ibid pp.2.3.2)

Natural Capital: "the natural resource stocks from which resource flows and services (e.g. nutrient cycling, erosion protection) useful for livelihoods are derived" (ibid, pp.2.3.3)

Physical Capital: "Physical capital comprises the basic infrastructure and producer goods needed to support livelihoods.• Infrastructure consists of changes to the physical environment that help people to meet their basic needs and to be more productive. • Producer goods are the tools and equipment that people use to function more productively" (ibid, pp.2.3.4)

Financial Capital: "namely the availability of cash or equivalent, that enables people to adopt different livelihood strategies" (ibid, pp.2.3.5)

(For extended explanation of the sustainable livelihoods framework please refer to the DfID, 1999, Sustainable Livelihoods Framework).

While the focus of the current impact assessment did not specifically address information from a sustainable livelihoods perspective, the CRED project has a very strong sustainability focus therefore lends itself to a rudimentary sustainable livelihoods analysis: community perceptions of the CRED project benefits will be analysed from this perspective, (see Table 11 below for summary of benefits).

BENEFITS	Human Capital	Social Capital	Natural Capital	Physical Capital	Financial Capital
Increased students study time (improved grades/job prospects/better studying environment)	X				
Savings on phone charging	X			X	X
Close location for charging (time and transport saving)	X			X	X
Contributes to community fund	X			X	X
Increased group meetings		X			
Cold drinks close by					X
Household energy savings					X
Less competition for communal energy sources at household level				(X?)	
Teachers prep in the evening (financial outlay for school lighting)	X				X
Respiratory health improvements/hshold air quality.	X		X		
Vaccines kept locally	X				
Extended emergency health hours	X				
Better working environment for health workers and better health care provision	X				

Table 11: CRED Sustainable Livelihoods Benefits

Human capital: This is important because human capital is necessary in order to command the other 4 dimensions of the sustainable livelihoods framework. Human capital has been directly improved by the solar installations in a variety of ways. Students report more and improved study time. Teachers confirm that student marks have improved since the CRED solar installation. Also people feel more confident about going to the health facility in the evening (e.g. it is safer) and in the event of an emergency after dark it is health assistance is easier to administer due to lighting (previously the HSA would use his mobile phone light). Further, health staff are happier that they have an improved facility which contributes to improved health provisions within Mwanayaya.

Directly contributing to the advancement of the following project objectives:

- Increased numbers of students at school during the increased hours of study through school lighting systems.
- Increased standards of health through refrigeration, clinic lighting.

Social capital: It is evident in the responses from all stakeholders that there has been a substantial increase in the number of social groups who use the school as a meeting point for various religious and social activities. Whilst the implications of increase increased social meetings on livelihood strategies are not directly ascertainable from the present consultation, initial indications suggest that there is potential for the CRED project to have positive impacts on social capital. Future investigations should aim to investigate this more directly.

Natural capital: Initial observations suggest there might be less impact on natural capital from the CRED project. Improved household air quality was the only mention of a natural capital related benefit that CRED impacted upon.

Physical Capital: That CRED is an electrification project in itself means that its primary impact is on physical capital. Solar deployment facilitates clean affordable energy intrinsically and also facilitates access to communication through providing a low cost and local phone charging facility.

The secondary impacts this has are 'human capital' oriented: students indicated that they use their mobile phones to contact their parents for school supplies when they are staying at the school over exam periods and to get help with homework, thus through CRED improvements in physical capital are interlinked with human capital benefits. This inter-linkage is further highlighted considering the most unanimously reported benefit that CRED has brought is to the students' increased ability to study in the evening. Further, some stakeholders highlighted their desire that the profits from the solar income generation activities, be utilised for the purchase of bricks for new school construction, demonstrating the potential for further contribution the CRED project could make to physical capital.

Financial Capital: The primary means by which CRED impacts on financial capital within Mwanayaya is through its income generation capacity. It facilitates the accumulation of a community fund which has the potential to contribute to various livelihood strategies. However, while there is potential to increase the financial capital of the village, this is also the area for the greatest potential for conflict. There are divergent views currently held regarding the use of funds generated through the solar income generation activities and also a feeling of lack of decision making equality and participation regarding what should be done with the profits.

Secondary impacts on financial capital are highlighted at the household level where financial outlay for lighting is reduced due to the communal evening study area provision for the students and similarly through reduced phone charging rates and transportation costs for energy supplies and pone charging. Students also report that household fuel savings are redirected into the purchase of school supplies thus indicating a tertiary impact on human capital.

The suggested 'upgrades' expressed by the stakeholders such as barber shop and increased phone charging capacity would also have income generation potential contributing to a strengthened 'Financial Capital' sustainable livelihood strategy.

These factors contribute to the following CRED project objectives:

- Increased awareness of the income generation potential of renewable (solar) energy in rural communities.
- Increase in additional income generation activities.

Currently the CRED project appears to contribute strongly to three areas of the sustainable livelihoods framework: Human capital, Physical capital and Financial capital. The other aspects of the framework (social and natural) appear to be less immediately evident from the responses gathered in the current consultation. While there appears to be a wealth of positive impacts on livelihood strategies offered by the CRED project, a more detailed analysis seated in this framework is fundamental to draw firm conclusions regarding sustainable livelihood impacts.

7.4. Discussion

The data collection process has provided useful insights into the success of the PV installations.

- The concept of an Energy Committee with local responsibilities was readily adopted
- Students are the most regular users of the evening lighting with large numbers taking advantage of the facility.
- Several other community groups utilise the evening lighting on a regular basis.
- The energy committee and field coordinator are facilitating access to the resource and managing the security and maintenance of the systems.
- Income generation from mobile phone charging and 12V battery charging has been highly successful.
- Fridges have been primarily used for drinks cooling
- Income generation from cold drinks is limited.

The CRED project has successfully demonstrated:

- Establishing and training a village Energy Committee
- Supporting Energy Committees via a support chain of local Field coordinator and city based project management
- Providing wide community access to electricity resources installed at Schools and Health Posts
- Accurately recording the daily use of the system by various community groups
- Undertaking income generation activities with the potential to cover the expected ongoing system maintenance costs.

Despite the success of the CRED project to date, there are many aspects to achieving a truly sustainable PV deployment model that require further refinement.

The technical issues encountered were predictable and overall the technical performance of the systems has been good. Continued improvement in DC lighting and battery technology will offer options for improved system design.

While the energy committee model has succeeded in promoting local ownership and participation, social development best practice can be brought to bear on improving the overall community ownership and participation.

Economic success in income generation and bank savings indicate a model that allows long-term maintenance costs to be covered locally after an initial external investment in infrastructure. However, given that the energy committee will then be responsible for handling significant sums of cash on behalf of the community, an open, transparent and accountable process needs to be implemented with full community agreement.

The learning from CRED is used in the following chapters to suggest a possible sustainable deployment model and the further work required to refine such a model.

8. Proposed model of sustainability

The term sustainability has been defined as "meeting the needs of the present without compromising the ability of future generations to meet their own needs2 (UN, 1987). The concept of sustainable development can be linked to electrical energy by what is called sustainable energy development and can be defined as "energy development that will require electricity services that are reliable, available and affordable for all, on a sustainable basis, world-wide" (Ilskog, 2005). The same author goes on to outline the following requirements for sustainable rural electrification.

- Technical sustainability
- Economic sustainability
- Institutional sustainability
- Environmentally sustainable
- Social sustainability

The above requirements highlight the need for an approach to the planning and design of renewable energy solutions that integrates the latest technical developments with current rural development thinking. The engineering approach must go beyond the technical and economic spheres.

This criteria has been addressed in the SURE and ITDG frameworks which provide a strategic approach to the development of rural energy solutions. (Brent and Kruger, 2009). The SURE framework focuses on the suitability of a technology to the local rural communities whereas the ITDG framework model assesses environmental resource, social development, economics and institutional requirements. The authors argue that there is huge challenge in the way renewable projects are managed. Additionally, meaningful sustainable energy development can only be achieved through participatory approach between society and renewable energy technology. Amid challenges that contribute to failure of renewable energy projects are weak or inadequate regulatory frameworks, lack of financial mechanisms and political risks, inadequate institutional capacity to implement projects and lack of background knowledge of the renewable energy projects in relation to what is feasible on the ground. Also various studies on renewable energy models in Southern Africa have shown that the social and political factors play similar roles to economic and technical factors in terms of sustainability of renewable energy projects.

The authors utilised the Delphi methodology to assess the two renewable energy framework models and subsequently developed a holistic, integrated framework of SURE and ITDG. The authors conclude that technological choice should always be a function of indigenous participation and structural arrangements and should also take into account effective institutional arrangements for the benefit of the local people.

The World Bank have extensive experience in the support of energy infrastructure projects and have also addressed the issue of sustainable off-grid electrification (World Bank, 2008). The recommended principals and practices highlight key elements of project design as: practical technology choices, least cost design, appropriate delivery mechanisms, community involvement, maximising productive applications, exploring international co-financing, Government ownership and consistency with rural electrification plan.

8.1.Community based approach for sustainable PV systems

The above recommendations on sustainable energy and rural electrification can be favourably compared to the CRED approach of a community scale PV system for improved education and health facilities as illustrated in Figure 5. The environmental sustainability of PV systems is assumed to be positive with respect to carbon, however issues around the materials involved and the current reliance on lead acid batteries are worthy of further discussion.

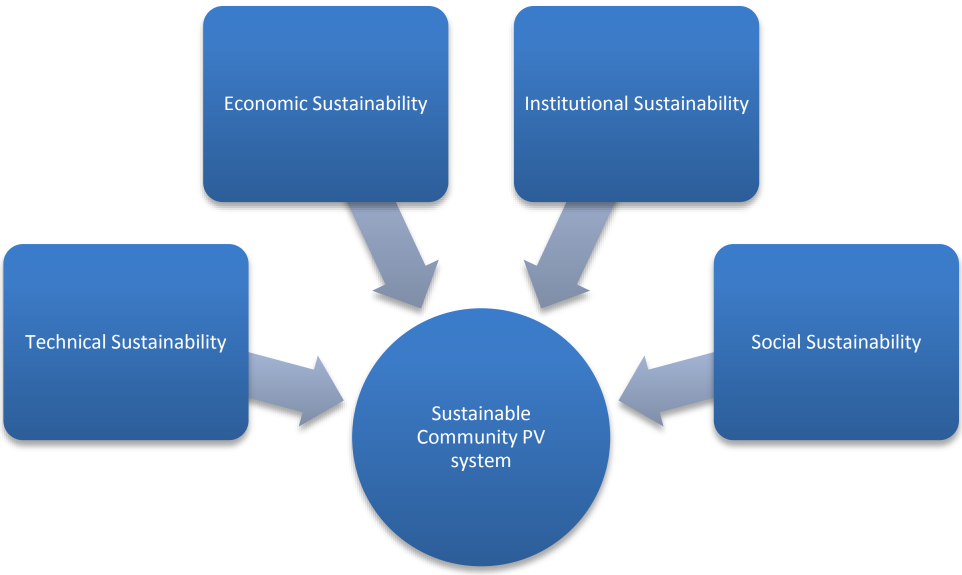


Figure 5: Sustainable community PV system

The elements of sustainability identified above are discussed in detail below.

Technical sustainability: The design process of PV systems includes assessing peak load, average daily load, solar resource, days of autonomy and the resultant choice of PV panel, battery technology and charge control and inverter electronics. This design process is well established and described in detail in many texts. Here we assume that good, standards based technical design is a pre-requisite of technical sustainability but not a guarantee. The technical sustainability is equally influenced by ensuring appropriate use, correct maintenance and access to properly trained engineering support in the event of failures.

Economic sustainability: The economics of PV are often discussed in terms of market based situations, investment recovery and general affordability. In this context the upfront investment for the PV system is assumed with the justification for subsidised investment generally provided by a requirement for improved education/health. Our definition of economic sustainability centres on the post installation recurring costs.

Institutional Sustainability: In this context, institutional sustainability concerns the organisational structures bearing influence on the local community. These include Government (particularly local government structures), health and education policy and administration, and village traditional authority structures.

Social Sustainability: The social aspect concerns the general interaction of the community with the PV installation, particularly: participation, ownership, and accountability of the local users.

The proposed approach to achieving sustainability in these areas is based on community focussed system design and a community ownership model. These two core aspects of the sustainable model and the influence links to the key sustainability factors are illustrated in Figure 6.

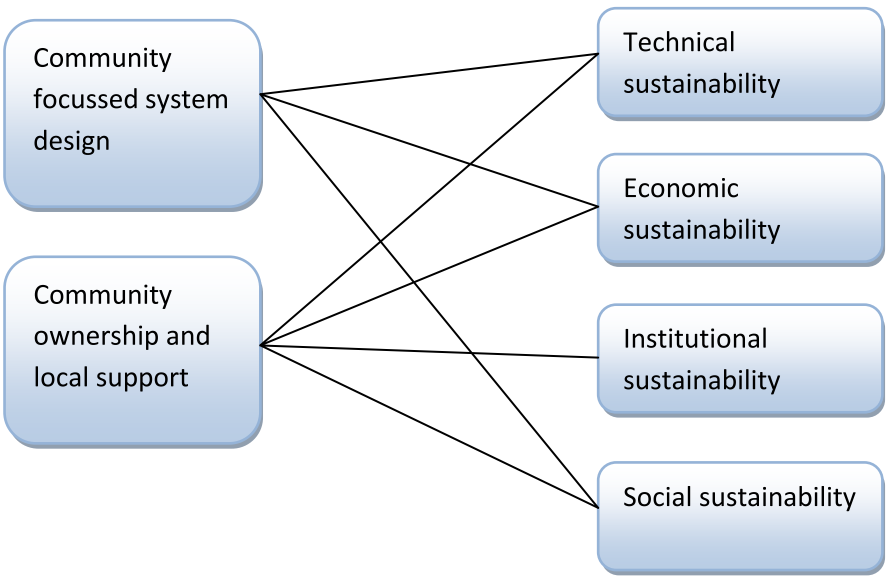


Figure 6: Community based model

8.2. Community Focussed System Design

Standard practice has been to design a PV system for the core requirements of a school or health installation. The proposal here is that system design must be viewed from a community perspective to maximise potential benefit and exploit income generation opportunities.

Inputs to the design process include: PV system design standards, locally available technology, budget, core load requirements, additional load implications of wider community use and income generation activity.

Technical sustainability is influenced by standards based design and the use of locally supplied technology for ease of maintenance. Economic sustainability is influenced by design to allow for income generation with minimal additional infrastructure. Social sustainability is influenced by design to maximise participation and access to the wider community.

8.3. Community Ownership

Positioning the electrical system as a community resource allows for greater engagement and participation from the wider community. Although health and education facilities are owned by the responsible government agencies, it is common practice for local communities to play an active part in sustaining and maintaining the facilities. The proposed approach is that the electrical infrastructure is also thought of in this way. Not necessarily physically owned by the community, but a resource that improves the lives of the community that will deteriorate and fail without their contribution. The proposed model for community ownership is via an Energy Committee. The committee would be formed through acknowledged local process and represent the community's responsibility for the maintenance, security and responsible use of the system. The committee works in partnership with the responsible health and education employees to ensure the core functionality is prioritised but that wider community access and income generation is facilitated. Appropriate community sensitisation and training is central to establishing a functional energy committee.

Key to the success of the local energy committees is the support that is available to them for technical support and ongoing knowledge transfer. In addition to the need for additional training, the energy committee will need regular refresher training and encouragement in their activities. In the event of technical failures, the committee will also require trusted advice and access to maintenance engineers.

The energy committee influence technical sustainability by ensuring appropriate use, providing basic maintenance, security and recognising the need for maintenance engineers. Economic sustainability is influenced by the committee taking responsibility for income generation and the growth of a maintenance fund. Institutional sustainability is influenced by providing appropriate community representation working with the approval of education/health administration and local traditional authorities. Local representatives formally taking responsibility for the system influence social sustainability as does the facilitation of wider community access. Local support is essential for technical sustainability in the event of maintenance issues. Continued knowledge transfer and capacity building of the energy committee influence the social sustainability.

9. Recommendations

The proposed sustainable deployment model relies heavily on a community centred approach with external support and input in the form of training and capacity building. To be a viable option for wide scale deployment the following areas need to be addressed.

- The adoption of a suitable development framework that can be applied throughout the life of an energy project from needs assessment to project design to impact assessment and evaluation. The use of the SLF in energy projects and its potential to achieve high levels of participation in a community energy project should be investigated.
- Mechanisms that can be scaled to a regional or national level are required to support communities exploit renewable energy technologies. Opportunities to include energy in the existing development structures in place in Malawi to avoid duplication of resource should be investigated along with the possibility for remote monitoring of renewable energy installations.

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Appendix A

24. OBJECTIVE(S): List the Objective(s) for this project and the Outcome(s) you expect the project to achieve ***See Note 1 in Section D of the Guidance Notes***	
Objective(s)	**Outcome(s)**

To increase the opportunities for social and economic development through increased access to reliable, affordable electrical energy in rural communities.	• Successful installation of pilot Community PV systems in four communities within the Chikwawa district. • Increased awareness amongst rural community members of applications of renewable (solar) energy in rural communities. • Increased awareness amongst rural community members of the income generation potential of renewable (solar) energy in rural communities. • Increased community involvement in specification, ownership and management of a community renewable energy resource. • Increased community involvement in the financial and technical maintenance requirements of solar energy systems. • Increased agricultural output though solar irrigation. • Increase in productivity time, especially for women and children. • Increase in additional income generation activities. • Increased numbers of students or increased hours of study through school lighting systems. • Increased standards of health through refrigeration, clinic lighting, water pumping.
To develop and increase the capacity of key stakeholders to advance GoM off grid rural electrification programme.	• An established and demonstrated sustainable model for rural community social and economic development based around PV installations in the Chikwawa district. • An increased understanding through demonstration of the remaining barriers to a community energy system. • An increased understanding of the potential a community energy model provides with regards to overcoming barriers to "off-grid" electrification. (This will supplement the outcomes of BARREM, a UNDP funded national programme concentrating on removing national barriers to the PV industry in Malawi) • An increased appreciation of the importance of community support (field community development and support workers) to assist project development and ongoing sustainability. • An increased appreciation of the importance of a community scale micro-finance scheme. • Increased local (Blantyre) capability to expand deployment in the Chikwawa district and elsewhere. • Increased local (Blantyre) confidence in the likelihood of success in such projects. • Increased availability of supportive training materials.

25. Activities: Please list the tangible Activities that the project will deliver. ***See Note 1*** **in** ***Section D of the Guidance Notes***

Pre Project Activities

September 2008 (i.e. pre award from Scottish Government)

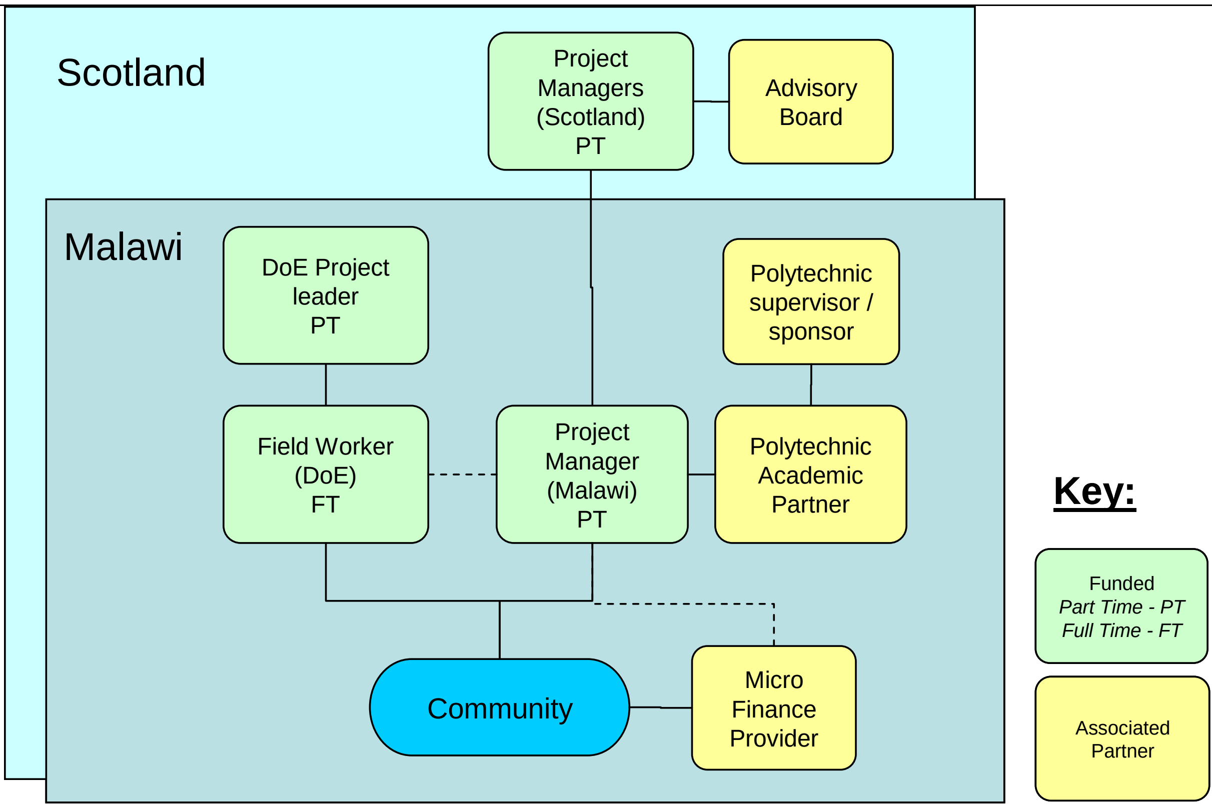
- UoS project manager full time in Malawi.
- Engage with the communities identified from existing Strathclyde Health Initiatives.
- Initial project team meetings and knowledge sharing.

Project Initiation (i.e. after funding notification, prior to kick off date)

October 2008 – December 2008

- UoS project manager full time in Malawi.
- Translation of HICEC community renewable energy development model
- Initiate community energy committees.
- Identify most pressing energy requirements per community.
- Develop relationships with the identified potential microfinance partners.
- Develop existing and identify additional enterprise activities.
- Establish an agreed microfinance approach for community energy with chosen partner.
- Advisory Board and Project Manager meetings.

The relationship of the partners in the project is lustrated in the diagram below:



<u>Project Kick Off</u>

January – August 2009

- UoS project manager full time in Malawi.
- Scope and design solar energy systems.
- Tender for local system supplier.
- Develop training materials.
- Project team training and preparation.
- Deliver training in PV system maintenance and community enterprise development to community committees.
- System installations.
- Field worker support commences.
- Initiate enterprise activities.
- Initiate and embed communities role
    - Microfinance agreement
    - System maintenance and management
- Establish and embed smooth operation of energy system.
- Support enterprise activities.
- Commence monitoring activities.
    - Community Logbooks
    - Fieldworker interviews
- Gather initial results and feedback.

<u>Ongoing support and monitoring</u>

September 2009 – March 2010

- UoS Project management visits.
- Continued field worker support
- Logbooks to capture monitoring information.
    - Technical
    - Economic
    - Social Benefits
    - Community approach
- Field worker collates monitoring information
- Weekly/Monthly monitoring and information gathering by field supervisor.
- Data analysis by Polytechnic partners.
- Monthly project management reporting.

Pilot Project Closure and Ongoing Programme Development

April – December 2010

- Ongoing support of rural communities through Field Worker, Project Leader, Project Managers and Field Supervisor
- Transfer full project leadership and management responsibility to Malawi partner (Dept of Energy)
- Report and Document project outcomes and proposed sustainable model.

The sustainable model of renewable energy based community development being deployed in this pilot project is illustrated below: